Elementary Mandarin Immersion Students Learning Alphabetic Pinyin and Using Pinyin to Learn Chinese Characters

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Abstract

As a critical component of literacy curriculum, alphabetic Pinyin can be introduced to Mandarin immersion (MI) students either at Grade 1, Grade 2, or Grade 3, together with another two orthographies: Chinese characters and English. When to introduce Pinyin and how to use Pinyin has been a practical and theoretical issue that matters to thousands of MI students in the US. However, very few studies have been conducted to investigate Pinyin literacy development and its relationship with Chinese character literacy development in young Chinese L2 learners.

Using a three-paper dissertation format, this project included three interrelated studies to examine (1) the extent to which Pinyin spelling skills predict Chinese word reading after controlling for a set of Pinyin literacy and Chinese character literacy related skills, (2) whether Pinyin captions in reading materials facilitate or hinder the learning of Chinese words in meaningful reading activities, and (3) the extent to which MI students have acquired Chinese sounds in absence of Pinyin instruction and developed Pinyin spelling skills after learning Pinyin for almost an academic year. Seventy-six English proficient third graders were recruited as participants from an early total MI program. Students learn the school subject matters via the medium of Chinese since kindergarten with 90% of instructional time allocated in Chinese. Students receive seven English language arts classes per week since Grade 2 and Pinyin instruction begins at Grade 3.

Study 1 is a correlational study that collected data from a set of Pinyin literacy and Chinese character literacy related measures. Hierarchical linear regression analyses suggested that the holistic Pinyin spelling or the separate Pinyin onset-rime spelling made

a significant and unique contribution to Chinese word reading above and beyond other identified variables. Study 2 is an experimental study that employed a crossover design to compare MI students' Chinese word learning with and without Pinyin. Contrast analyses and multilevel model analyses showed that students learned the Chinese words better without Pinyin, but the differences were not beyond significance level. Study 3 examined Chinese phonology acquisition and Pinyin spelling. Speech and spelling error analyses suggested that MI students could achieve high accuracy in pronunciation, but exhibited challenges in Pinyin spelling, mostly due to the negative transfer from L1 English literacy knowledge, insufficient phonological sensitivity, and incomplete Pinyin letter knowledge.

Although Pinyin spelling skills can predict Chinese word reading, it does not mean Pinyin instruction, seen as phonological training, could promote Chinese word reading, which requires the experimental design. In fact, the use of Pinyin may interfere with the learning of Chinese words in teacher-involved reading activities. Additionally, there might be cognitive constraints for young Chinese L2 learners to learn Pinyin. More importantly, Chinese reading acquisition may depend on meaning. The findings together suggested to allocate precious instructional time in early academic grades to develop MI students' character knowledge and oral vocabulary knowledge, especially the more abstract Tier 2 words. Furthermore, Pinyin captions should be avoided in whole group reading activities where the teacher can provide instructions on the new words. In all, late Pinyin introduction should be encouraged in most MI programs. The findings are of importance for MI educators to make curricular decisions on when to teach Pinyin and how to use Pinyin for English L1 young learners of Chinese.

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Chapter 1

Introduction

1.1 Why Should We Care?

One day in 2018, I received an email from a Mandarin immersion (MI) teacher in California looking for suggestions on the topic of Pinyin introduction and Chinese character literacy development in their program. In her email, she states,

> To date, we have been introducing Pinyin in 2nd grade and some stakeholders have asked to see if we might look into introducing and using Pinyin as early as kindergarten. At your convenience, I would appreciate your expertise and direction on where to find any specific research supported data, articles or journals on this matter.

This curricular conundrum in MI programs is not new. The debate on when to introduce Chinese characters and the alphabetic Pinyin system has been ongoing in Chinese foreign language teaching in the US and in European countries for decades (Ye, 2013). Some educators believe that Chinese characters should be taught to Chinese second language (L2) learners at the beginning of their foreign language education, but others think alphabetic Pinyin should be first taught to and used with Chinese L2 learners who have an alphabetic language background. It is important to note that most existing research studies were conducted with college-level adult learners of Chinese, who have tremendous differences in cognitive, social, emotional factors, learning strategies and resources, etc. However, the research on young learners of Chinese has been scarce. With the rapid growth of English-speaking children who learn Chinese as L2 in the MI programs, the topic of Pinyin introduction becomes even more critical, because these English L1 children need to develop high proficiency to read and write in Chinese.

1.2 Mandarin Immersion Education and Chinese Reading Proficiency

Mandarin immersion is a newcomer to immersion education, but it has become a popular program model in North America. As an alternative/supplemental educational program to the public education system, language immersion has been the most successful school-based foreign language program model to achieve academic success and a high level of L2 proficiency at no cost to their first language (e.g., Genesee, 2004; Hamayan, Genesee, & Cloud, 2013; Lindholm-Leary, 2001). This educational model aims to help students with three overarching goals: achieve academic success, attain bilingualism and biliteracy, and develop a highly sensitive understanding of the target culture and intercultural communication skills (Howard & Christian, 2002). The majority of MI are one-way world language immersion programs that enroll students with English L1 linguistic background with the same goal of becoming proficient in Chinese L2. Based on a self-reported school list of 224 elementary MI programs in the US (Mandarin Immersion Parent Council, 2019), 65 programs known as the early total programs show 90% or 80% of the instructional time as allocated to Chinese, also known as 90/10 or 80/20 models. Furthermore, nine programs allocate 75% to 60% of the instruction in Chinese, and 150 programs chose the early partial or the 50/50 model, with half of the instructional time in Mandarin and the other half in English.

In early total immersion curriculum, students are usually introduced to L2 language and literacy first and then L1 literacy, with an intention to maximize L2 language and literacy input. The idea of early total immersion is based on the findings from previous research that students in early total immersion programs attained higher

language proficiency than did students early partial programs (e.g., Genesee, 1987; Lindholm-Leary, 2001). In early total MI program models, children are taught the Chinese characters first since kindergarten and L1 English literacy begins at Grades 2 or 3. Some programs introduce Pinyin first in Grade 1; some delay English literacy until Grade 2 and then teach Pinyin in Grade 3. In early partial programs, children are taught to learn school subjects a half day in Chinese and half day in English. Pinyin is usually introduced in Grade 2 or Grade 3. Additionally, of all 306 MI programs in the US, 262 choose simplified Chinese scripts and only 44 programs still teach traditional Chinese scripts (Mandarin Immersion Parent Council, 2019).

Recent literature on one-way MI students' Chinese language proficiency achievements reports that reading in Chinese was rated the lowest among the four skill areas of listening, speaking, reading, and writing (Burkhauser et al., 2016; Fortune & Song, 2016; Watzinger-Tharp, Rubio, & Tharp, 2018). The findings in Burkhauser at al. (2016) and Watzinger-Tharp et al. (2018) are consistent in that, in 50/50 models, MI students' reading scores on average were about two sub-levels lower than their peers who were enrolled in alphabetic immersion programs, according to standardized language proficiency tests. Fortune and Song (2016) report that, in 90/10 programs, MI student reading levels spread wide across Novice Mid to Intermediate Mid, rated by the proficiency levels adapted from the American Council on the Teaching of Foreign Languages *Proficiency Guidelines* (ACTFL, 1986, 1999). Taken together, the findings across three recent studies suggest that reading in Chinese is challenging for MI students. However, reading is usually the second or the highest skill area for immersion learners of

alphabetic languages (Burkhauser et al., 2016; Genesee, 2004; Watzinger-Tharp et al., 2018). The low performance in reading of MI students has caused rising concerns because, if these children are at novice levels in reading, they are not able to learn complex school subjects in Chinese. Obviously, character literacy is a challenge for MI students and warrants empirical study before pedagogical and curricular innovations.

1.3 Statement of the Problem

Pinyin introduction in MI education is a complex topic because it is related to two other orthographies, i.e., the Chinese characters and English, and it also depends on Chinese phonological development for English proficient young learners. In the first few years of schooling, MI students are introduced to the three orthographies: Chinese characters, alphabetic English, and alphabetic Pinyin. In these three orthographies, Chinese characters and English are the orthographies that people use to read and write. People do not read or write in Pinyin. The invention of Pinyin is to provide standard pronunciation for the Chinese characters in 1950s (Committee of Chinese Writing System Reform, 1958). Pinyin is also widely used for Chinese L2 learners to access to Chinese phonology (Ye, 2013). Additionally, Pinyin input method has been predominantly used to type Chinese character on digital devices. The central question about which MI educators have been concerned is whether the use of Pinyin can facilitate or hinder the learning of Chinese characters for young Chinese L2 learners. This practical question matters to over 20,000 students' everyday school experiences and their Chinese reading acquisition.

Pinyin introduction in MI programs is also related to English literacy. Most MI learners have some basic English literacy even before being enrolled in their programs in kindergarten, or they have been introduced to English literacy before they are taught Pinyin. English and Pinyin are both alphabetic orthographies. Another question about Pinyin literacy development is in regard to the extent to which MI students can read and spell Pinyin when they have had English literacy instruction.

Pinyin introduction is related to MI students' phonological competences. In college level Chinese classes, learners are often introduced to Pinyin to learn Chinese pronunciation (Ye, 2013). The third related question is whether young MI students can achieve high accuracy of Chinese pronunciation without Pinyin. Additionally, Pinyin spelling depends on the spellers' phonological competences. Therefore, it is important to understand their mental representations of the Chinese sounds, which could be useful to explain their Pinyin spelling errors.

1.4 Research Questions and Hypotheses

The primary goal of the dissertation is to provide empirical evidence on when to teach Pinyin and the role of Pinyin in the overall literacy development of young MI students who are English proficient. I designed three separate but related studies to provide empirical evidence to address the broad questions. The central questions in each study are identified as follows.

Study 1

(1) To what extent does Pinyin spelling predict Chinese word reading in Grade 3 MI students after controlling for a set of literacy-related variables identified based on the current theoretical understanding of learning to read in Chinese?

Study 2

(1) Does the use of Pinyin facilitate the learning of Chinese words for MI students (i.e., knowing the pronunciation and explaining the meaning) in meaningful reading activities?

(2) To what extent is knowing the pronunciation associated with being able to explain the meaning of the Chinese words?

Study 3

(1) To what extent do MI students in absence of alphabetic Pinyin instruction acquire Chinese phonological elements at the beginning of Grade 3? What are the characteristics of their L2 Chinese phonological acquisition?

(2) To what extent do MI students develop Pinyin spelling proficiency after systematic Pinyin instruction towards the end of Grade 3? What are the characteristics of Pinyin spelling development in MI students?

In the first study, I hypothesize that Pinyin spelling skills will not be a significant predictor of Chinese word reading after controlling for a set of character and Pinyin literacy-related variables. For the second study, I hypothesize that Pinyin notation in learning materials will not facilitate the learning of the unfamiliar Chinese characters.

The recall of a Chinese word's sound and meaning should be significantly correlated. Lastly, I hypothesize that MI students will achieve high accuracy in Chinese pronunciation without Pinyin and their Pinyin spelling proficiency can be influenced by their phonological errors and their English literacy knowledge, and therefore, they will not achieve high proficiency in Pinyin spelling after learning Pinyin for an academic year toward the end of Grade 3.

1.5 Significance of the Research

The three studies together could provide empirical evidence to suggest when to introduce Pinyin and how to use Pinyin for MI students. With regard to the first two studies, the use of observational and experimental design aims to clarify two distinct methodologies of researching Pinyin and Chinese literacy development. The first study used observational design to examine the correlational relationship between Pinyin spelling and Chinese word reading; the second is an experimental study that investigates the causal relationship between the use of Pinyin and the learning of Chinese words. A popular approach in psycholinguistic research is to build regression models to understand correlations between the focal variable and the response variable, in this case Pinyin spelling and Chinese word reading. However, a caveat is that our interpretation of the parameters can be biased due to model specification and model selection issues, which will be explained in Chapter 3. This study contributes to the field by identifying the key literacy-related variables based on the current theoretical accounts of Chinese reading acquisition and the variables that are related to Pinyin literacy. In this study, it is

important to keep in mind that correlation may not suggest causation, which requires experimental design. The experimental study will examine the role of Pinyin in learning the sound and meaning of Chinese words. The findings in these two studies can help us understand Chinese character literacy development in relation to Pinyin for MI students.

Another pedagogical contribution of the study is to fill the gap in understanding English-Chinese bilingual children's phonological competence in early total MI programs. Although there is no agreement on the critical period hypothesis for second language acquisition, a substantial body of research indicates that one of the advantages of learning a foreign language at a young age is to acquire the L2 phonological system more readily and efficiently (e.g., Flege, Yeni-Komshian, & Liu, 1999; Kuhl, 2004; Munro, Flege, & MacKay, 1996). Earlier research on immersion students' pronunciation suggests that immersion students do not achieve native-like pronunciation (Harada, 1999; Menke, 2010; Snow & Campbell, 1985). However, there is a general lack of understanding of what phonological acquisition looks like for English L1 children acquiring Mandarin Chinese. What phonological elements are challenging for MI students to acquire? What do MI students transfer from English L1 phonological systems to acquire Chinese L2? Because immersion education is primarily content-driven, the findings on their Chinese pronunciation can provide valuable information for MI teachers to provide corrective feedback and specific instruction on students' pronunciation in classroom discourse.

Lastly, the present study is the first in the under-researched area of Pinyin literacy acquisition. In fact, very few research has been conducted on Pinyin learning, either for

Chinese L1 or L2 children. Is Pinyin easy or difficult to acquire for children who speak English and are acquiring English literacy? What Pinyin symbols are easier or more challenging to learn? How does the English literacy influence their learning of Pinyin spelling? This information will be valuable for MI teachers to provide cross-language activities to teach Pinyin to MI students. Taking these findings together, MI teachers and program leaders could make informed curricular decisions on when and how to introduce Pinyin in their MI programs.

1.6 Overview

This dissertation employs an alternative format by presenting three studies to address the separate but interrelated research questions on Chinese character literacy and Pinyin literacy. Chapter 2 will begin with a brief introduction on Chinese character orthography, followed by a critical review of the major theoretical accounts on reading acquisition in Chinese. The following three chapters host three studies: The first study is the observational study, entitled "Understanding the Relationship between Pinyin Spelling and Chinese Word Reading." The second study is an experimental study, entitled "Does the Use of Pinyin Facilitate the Learning of Chinese in Meaningful Reading Activities? Evidence from Elementary Mandarin Immersion Students." The third study, "Learning Chinese Sounds and Pinyin Spelling in Elementary Mandarin Immersion Students," is also an observational study that analyzes the qualitative data of Chinese sounds and Pinyin spelling. Chapter 6 discusses the implications of when to

introduce Pinyin and how to use Pinyin for MI students and theorizes Chinese reading acquisition for research on Chinese L2 children.

Chapter 2

Theoretical Frameworks on Learning to Read in Chinese

In this research project, I primarily focus on the relationship between Pinyin literacy and Chinese character literacy development, but the ultimate goal of this dissertation is to contribute to Chinese character literacy development. For the last two decades, a body of research has documented Chinese reading acquisition for first language (L1) and second language (L2) learners for two reasons. First, the attention toward researching Chinese comes from the distinct features of the Chinese writing system from alphabetic languages (Perfetti & Dunlap, 2008). The second reason is the dramatic increase in the number of English speakers in the world learning Chinese as a foreign language in various types of programs in the last two decades (Ke, 2012; Mandarin Immersion Parents Council, 2019). More research is needed to understand Chinese literacy acquisition and Chinese-English biliteracy development. This chapter begins with an introduction on the writing system of Chinese characters. Next, it is followed by a critical review of the current theoretical accounts on learning to read in Chinese, in comparison to the most documented research on English reading acquisition. The chapter will end with a discussion on the potentials of cross-language transfer in learning to read the Chinese characters, English, and Pinyin.

2.1 Distinct Features of the Chinese Characters

Based on the mapping principles of how spoken languages are represented in writing systems, the three major writing systems are alphabetic, syllabic**,** and logographic (Coulmas, 2003). Chinese is defined as *logographic*; that is, a graphic symbol represents a spoken word (Hoosain, 1991). The basic graphic unit of the Chinese writing system is a character. In classic Chinese, each character is a monophonemic word. In view of this criterion, *logographic* is a more appropriate term for classic Chinese. However, most words in modern Chinese are bisyllabic words that map onto two characters, in which each character is a bound or free morpheme and is holistically assigned to a syllable. Accordingly, Chinese is also referred to as a morphosyllabic language (DeFrancis, 1989). Some distinct features of Chinese characters are summarized as follows.

2.1.1 Size of Chinese Orthographic Components

The first distinct feature of Chinese orthography is the large number of characters. It is commonly believed that a literate person in Chinese can recognize 3,000 frequently used characters. As reported in Shu, Chen, Anderson, Wu, and Xuan's (2003) analysis on *School Chinese*, Chinese L1 children in mainland China are introduced to 2,570 characters in elementary grades. Earlier research on the orthographies of Chinese characters and an alphabetic orthography of Kannada used in India suggested that the number of orthographic components is a dimension that explains the differences in the pace of reading development (Nag, 2007; Shu et al., 2003). Fortunately, Chinese characters do not consist of random strokes but recurrent components. The majority of

the characters are semantic-phonetic compound characters, which can be further summed to about 200 semantic radicals and 800 phonetic radicals (Hoosain, 1991). MI programs have lower expectations for character learning than in Chinese speaking societies, and these expectations differ greatly in various types of programs (compiled by Fortune & Lien, 2016; see Appendix A). In early total MI programs, students may be required to read and write 1,500 to 1,800 characters by Grade 5. However, in early partial programs, students may only be expected to recognize about 600 to 800 characters by Grade 5.

2.1.2 Consistency of the Chinese Orthography

Another dimension that impacts reading acquisition from alphabetic literacy research is the orthographic consistency. Due to a large number of irregular spelling and sound varieties in English in comparison to other European languages, acquiring a foundational level of reading in English is a much longer process than learning orthographically shallow orthographies, such as Finnish or Spanish (Seymour, Aro, & Erskine, 2003). Even though the term *orthographic depth* is used for alphabetic languages to describe the degree to which sound-letter correspondence rules vary in the European languages, some researchers argue that the Chinese is orthographically deep due to the fact that the semantic and phonetic information contained in the characters is not transparent or reliable (Hu & Catts, 1998). According to an analysis on the elementary Chinese language arts textbooks used in mainland China (Shu et al., 2003), of the 2,570 characters taught in elementary grades, 72% are made up of semantic-phonetic compound characters; of these compound characters, 58% have transparent semantic

radicals, which directly provide the meaning of the character. For example, 湖 (*lake*) has the component 氵, as the water radical to the left, cueing that the character is related to water. Another approximately 30% of the characters have semi-transparent semantic radicals, providing some information of the character, such as 足 as a foot radical in 距 /jù/ to mean *distance* indirectly. In addition, 9% of the characters have opaque semantic radicals that do not contribute to the meaning of the character.

Phonetic radicals, the other part of the compound characters, give clues as to the pronunciation of the character. Similar to English orthography, phonetic radicals are not very reliable in providing the syllabic information of the characters. The pronunciation of a compound character may be different from the phonetic radical in onset, rime, or tones. Shu et al. (2003) report that only 39% of compound characters include a phonetic component that gives reliable information as to the character's sound, including phonetic differences in tones. For example, 逗 is pronounced /dòu/, with a regular phonetic radical 豆 /dòu/ on the right side. About 26% of the compound characters are semi-regular; that is, the phonetic radical provides partial information of the character, with changes in onset or rime, such as the character pairs 兆 /zhào/ and 桃 /táo/ or 吉 /jí/ and 结 /jié/. About 15% of the characters are irregular characters, in which the phonetic radicals give no information about the pronunciation of the character, such as 京 /jīng/ as a radical in the character 凉 /liáng/.

2.1.3 Prevalence of Homophones

In English, there are some homophones, like *site* and *sight* or *too*, *to*, and *two*. The number of homophones in Chinese is much greater. In Chinese, there are about 400 syllables, or 1,200 possible tonal syllables that correspond to 3,500 characters (Chao, 1976). That means one syllable can correspond to many characters. The most famous example to illustrate the prevalence of homophones in Chinese is the story in classic Chinese titled 施 /shī/ 氏 /shì/ 食 /shí/ 狮/shī/ 史/shǐ/ (*A Story of Mr. Shi Eating Lions*), created by Chinese linguist Yuen Ren Zhao (Peng, 2009). In this short story, the author uses 31 visually different characters that share the same syllable, /shi/, with different four tones for all 92 characters. Without the mediation by orthographic information, it is impossible to understand the story by only using phonological information. Hence, orthography is important to differentiate identical sound representations in print; tone plays a crucial role in distinguishing sounds and meaning in spoken Chinese.

2.1.4 Orthographic Complexity

The other feature of Chinese orthography is the visual and spatial complexity of the characters (Shu et al., 2003). Some simple characters are composed of similar stroke patterns to represent different meanings and pronunciation. For example, 工 /gōng/ (*work*), 土 /tǔ/ (*earth*), 士 /shì/ (*soldier*), 干/gān/ (*dry*), and 上 /shàng/ (*up*) are all made of only three strokes with different configurations. Some characters are composed of the same components but with reversed configurations, such as 杏 /xing/ (*plum*) and 呆 /dāi/ (*dumb*) or 部 /bù/ (*part*) and 陪 /péi/ (*to company*). Moreover, a minor change in one

component in the compound characters would change the character's meaning and pronunciation. For example, 请 /qǐng/ (*please*), 清 /qīng/ (*clear*), 情 /qíng/ (*emotion*), and 晴 /qíng/ (*bright*) share the same phonetic radical 青/qīng/ (*green*) but differ in sound and meaning. Remembering all the orthographic details in characters and how the differences in components and configurations could result in the change in meaning and pronunciation could be challenging for young learners.

2.2 Theories on Learning to Read in Chinese

To date, Chinese reading acquisition theories have been developed mostly with Chinese L1 children. These theories can be organized by two main perspectives: the mapping view and the componential view of reading. The mapping perspectives regard learning to read Chinese as a process of rote memorization, a progression through different stages, or a variation of the universal rules of mapping. On the contrary, componential view identifies the unique cognitive, linguistic, and metacognitive constructs that are related to reading acquisition. Some thoughts are provided to summarize and reflect on these current theories.

2.2.1 Rote Memorization

Learning to read is often seen as a rote memorization process of connecting the visual form and sound of the characters one by one (see a review in Jiang & Smith, 2009). This belief is reinforced by the fact that the literacy instructional activities designed in textbooks and used by many Chinese teachers are characterized as

repetitions, such as choral reading and hand copying (Li & Rao, 2005; Wu, Li, & Anderson, 1999; Zhang, 2009). Additionally, Chan and Wang (2003) argue that, before children acquire the analytical skills to derive or analogize the pronunciation of the unfamiliar characters, they rely on rote memorization to build the association between the sound and shape of a character because the majority of semantic radicals and phonetics in compound characters are not reliable to cue the meaning or sound of the characters.

2.2.2 Stage Models

Earlier research characterizes English reading acquisition in terms of stages as learners become more skilled in recognizing words (Chall, 1983; Ehri, 1998; Frith, 1985; Gough & Hillinger, 1980; Mason, 1980; Seymour & Duncan, 2001; Stuard & Coltheart, 1988). Three similar stages have also been evidenced in learning to read in Chinese as L1 and L2 (Chen et al., 2003; Kim, 2010). Similar to the English reading acquisition stages, Chen and her colleagues (2003) found that beginning readers of Chinese also start to read characters by relying on self-selected features of characters. Chen et al. (2003) call this strategy *visual reading*. Children may use a stroke or part of a character's configuration to associate the character with its pronunciation or meaning. The next stage by Chen and her colleagues (2003) is the phonetic stage, which corresponds to the alphabetic stage in English. At this stage, Chinese children read words by using their phonetic components or making analogies to other characters that contain the same components. The last stage is orthographic reading. This stage refers to the awareness and capacity to use phonetic consistency knowledge in reading unfamiliar characters, that is, using the most frequent

pronunciation of the phonetic radical to predict the pronunciation of the unfamiliar compound character. Kim reports that L2 learners at the college level bypassed the first stage of visual learning and learned characters from the phonetic stage. As their character knowledge increased, the learners proceeded to the orthographic stage. Kim tended to attribute the absence of the visual stage to two factors: the character knowledge the learners have acquired previously and/or working memory variations between children and adult L2 learners.

Different from Chen et al.'s (2003) stage model that emphasizes the development of phonological skills in learning to read, Ho, Yau, and Au (2003) posit that learning to read or write in Chinese may rely on the development of a set of orthographic rules, based on their study conducted with native Chinese speaking children. Chinese L1 children spend their whole elementary education developing orthographic knowledge from rule-based learning. The early exposure to characters helps them acquire the character configuration knowledge and character structural knowledge. With instructional input, children learn the meaning and sound of each individual semantic and phonetic component and develop the positional and functional knowledge of the radicals. Eventually, the hypothesis suggests that children could apply all levels of orthographic knowledge to achieve a complete set of character knowledge.

2.2.3 Learning to Read as Universal

Perfetti and his colleagues contribute to the field by providing a general picture of the universal principles of reading acquisition and the writing system variations (Perfetti

& Dunlap, 2008). In the theory of the Universal Grammar of Reading, Perfetti (2003) claims that the essential problem of learning to read is to uncover the relationship between one's writing system and the spoken language. This relationship is universal across all languages; that is, writing systems encode spoken language. He suggests that reading acquisition requires the learner to identify what linguistic units (i.e., phoneme, morpheme, or syllable) are used to represent speech (general mapping principle), and then learners work out the details of how speech is represented in the orthography (mapping details). Reading acquisition may vary in terms of the linguistic units that are used to represent print, as well as how each graphic unit maps onto speech in each orthography. To "crack the code" of alphabetic languages (e.g., English), children must understand that letters represent distinct sounds and work out the grapheme-phoneme correspondences within specific orthographies. Learning the alphabetic rules may take different lengths of time for children from various cultures. English children may take much longer time to acquire the rules than Finnish children because the sound-letter correspondence rules in English are much more inconsistent. The Grain Size theory posits that English children have to rely on more than one grain size in reading and applying the mapping rules (recoding) because the smaller grain size of phonemes tends to be more inconsistent than the larger grain size of rimes or syllables in English where there are many sound varieties and irregular spellings (Ziegler & Goswami, 2005). In contrast, when learning to read logographic languages, such as Chinese, children have to uncover that graphic symbols represent the sound and meaning of the characters and understand the specific way in which graphic symbols are used to represent sound.

Regardless of the differences across writing systems, the generalizable account of reading describes the *mapping* relationship between print and speech.

2.2.4 Componential View of Reading

Although it is true that foundation level reading and writing is about mapping sound to symbol, reading development is more than mapping. When children learn to read, a set of literacy-related skills and knowledge develop during and even before reading acquisition. The componential view of reading, proposed by Carr and Levy (1990), identifies the underlying cognitive skills and examines their relative contributions to reading acquisition. A line of research has focused on the cognitive and metalinguistic cores that are universal or unique for reading in alphabetic languages and Chinese (McBride & Wang, 2015; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001). These core skills are important for identifying the types of children who are struggling to read and making effective pedagogical interventions for normally developing and struggling readers (McBride & Wang, 2015).

The most researched core skill is phonological awareness, defined as the ability to identify, reflect, and manipulate the sound structure of spoken language (Ziegler & Goswami, 2005). The central question in learning to read alphabetic languages for children is to identify and represent the phonological elements with alphabets (Ehri, 1998). Different levels of phonological awareness have been found to have correlational and causal relationships with English reading acquisition (e.g., Goswami & Bryant, 1992; Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001). In other words, phonological

training could promote reading alphabetic languages. This research agenda on phonological awareness has also been applied to research Chinese reading acquisition.

A number of studies have reported that phonological awareness is significantly related to character reading for Chinese children (Ho & Bryant, 1997a; Ho & Bryant, 1997b; McBride-Chang & Ho, 2000; Shu, Peng, & McBride-Chang, 2008). Tasks that tap into syllable, onset-rime, and tone awareness are often used to reflect the features of spoken Chinese. Because learning to read Chinese does not require phonemic level sensitivity, phonemic awareness is often not considered important in learning to read Chinese (Anderson & Li, 2006). McBride and her colleagues suggest that invented spelling can be a better predictor than phonological awareness for subsequent reading development in English speaking children (McBride-Chang, 1998), and Pinyin spelling can be a more optimal method to gauge Chinese phonological awareness (Ding, Liu, McBride, & Zhang, 2015; Lin et al., 2010). The correlation between Pinyin spelling and Chinese word reading has been interpreted as causation for Chinese L1 and L2 children (Lin et al., 2010; Lü, 2017). However, in the current literature, the causal relationship between phonological awareness and Chinese word reading has not been established yet (McBride & Wang, 2015; Zhou, McBride-Chang, Fong, Wong, & Cheung, 2012). In fact, Zhou et al. (2012) found that phonological training at rime level did not facilitate the learning of Chinese for Chinese L1 kindergarteners.

On the other hand, a number of studies have identified morphological awareness as a core cognitive skill in learning to read Chinese. Morphological awareness refers to "the ability to reflect upon and manipulate morphemes and control word formation

processes" (Kuo & Anderson, 2008, p. 47), which can be seen as an umbrella term that includes grapho-morphological awareness and compound awareness. Grapho-morphological awareness is defined as "the ability to reflect upon how semantic information is encoded in the orthography and how orthography provides cues to meaning" (Kuo & Anderson, 2008, p. 54). Grapho-morphological awareness was tested by homophone awareness and sematic radical awareness, which are found to be crucial to individual character reading (McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003). Semantic radical awareness is particularly important to character reading because it gives a clue to a character's meaning and determines its pronunciation from other characters that share the same phonetic radical (Kuo & Anderson, 2008). Additionally, numerous studies have examined semantic radical awareness and its relationship to character reading for Chinese L1 and L2 readers (e.g., Ho, Ng, & Ng, 2003; Shen & Ke, 2007; Wong, 2017). Compound awareness is particularly related to Chinese word reading because the majority of Chinese words are formed with two characters. The findings in current research suggest that compound awareness is strongly associated with Chinese word reading for children in different cultures (McBride-Chang et al., 2003; Zhang, 2014; Zhou et al., 2015; Zhou et al., 2017), and this core skill has been employed to provide effective intervention for normally developing and struggling readers (Chow, McBride-Chang, Cheung, & Chow, 2008; Shu, McBride-Chang, Wu, & Liu, 2006; Zhou et al., 2012).

Orthographic awareness is also an important metacognitive skill for reading development (McBride & Wang, 2015). Similar to the role of letter knowledge and letter

combinations that are fundamental in English reading for emergent readers (Ehri, 1998), orthographic knowledge and skills are critical in learning to read in Chinese probably because of the large number of Chinese characters with complex configurations and components. A number of studies have taken into consideration the pure visual skills and Chinese specific visual orthographic processing skills in Chinese reading acquisition (Tong, Tong, & McBride, 2017; Zhou 2012). The significant difference in visual-orthographic skill between native Chinese-speaking and nonnative Chinese-speaking children contributed to their reading differences (Zhou et al., 2015). Training in orthographic knowledge and skills, such as hand copying, was found to facilitate Chinese word reading for Chinese L1 and L2 learners (e.g., Guan, Liu, Chan, Ye, & Perfetti, 2011; Tan, Spinks, Eden, Perfetti, & Siok, 2005).

2.2.5 Reflections on Current Reading Acquisition Theories

The aforementioned theories on Chinese reading acquisition provide a spectrum of perspectives on the complex processes of character literacy development. To sum up, the mapping reading theories describe the relationship between phonology and orthography, either by rote learning or rule-based learning. Slightly different, Perfetti (2003) posits two separate sets of mapping in Chinese: mapping a character to a syllable and mapping a character to a morpheme. The line of componential reading research identifies the core reading skills for character literacy development on each constituent of phonology, orthography, and semantics.

However, these theories do not seem to adequately capture Chinese reading development in either Chinese L1 or L2 children from two observations. The first observation is that the theories are not able to explain that Chinese L1 children can successfully learn about 500 new characters each year on average for six years given the fact that Chinese does not have transparent sound-symbol correspondence and a large number of homophones exist. It is very challenging to learn hundreds of Chinese characters by rote memorization. Besides, Chinese characters are likely taught in a dispersed fashion for both Chinese L1 and L2 children because most semantic and phonetic radicals appear in textbooks and reading materials sporadically, rather than organized in a concentrated way to facilitate the rule-based learning (Cui, 2008). The second observation is that knowing the pronunciation and being able to explain the meaning of the Chinese words are strongly correlated (Everson, 1998; Jiang, 2003; Zhao, 2003). In fact, a moderate association is also observed between decoding English exception words and English oral vocabulary knowledge (Ouellette, 2006; Ricketts, Nation, & Bishop, 2007; Scarborough, 2001).

A different and important view on learning to read proposed by Ouellette (2006) who suggests that oral vocabulary knowledge is important in decoding irregularly spelled words and should be incorporated in the current developmental theories of reading acquisition. That is to say, decoding may rely on meaning when the phonemic level letter-sound correspondence is not available. As he argues,

> Although direct connections between orthographic representations or spelling and pronunciation have been proposed as the basis of sight-word reading (Compton, 2002), both phonological and semantic processes may be necessary in establishing (and retrieving) the original representation. Thus, decoding of

> orthographic representations and associated phonology may be related to the ability to encode both phonemic and semantic information and to subsequently access and retrieve this information. (p. 562)

Based on the triangle framework of word reading that involves the activation of phonology, orthography, and semantics (see Figure 1; Seidenberg & McClelland, 1989), the direct route between orthography and phonology and the indirect route through semantics are known as the dual-route model of word reading (Baron & Strawson, 1976). Ouellette (2006) notes that decoding regularly spelled words is more related to phonological awareness, the ability to pay attention to lexical details, whereas decoding irregularly spelled words is more associated with the semantic representation of a lexicon, that is to say, relying on the route of semantics.

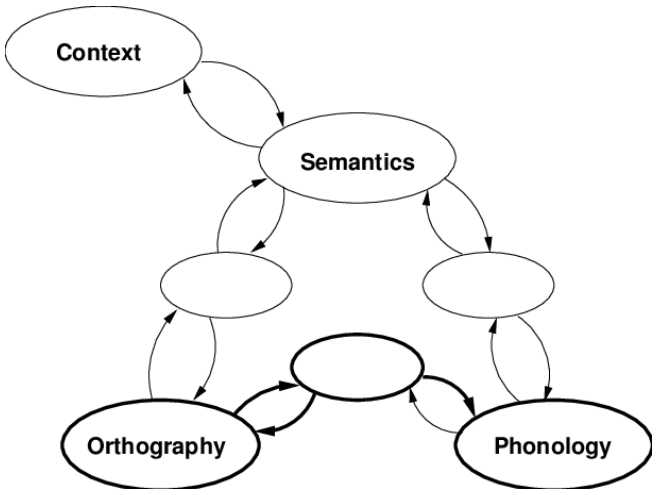

Figure 1. The triangle model (Seidenberg & McClelland, 1989)

The role of meaning in word recognition applies to English reading acquisition at some developmental stages (Ehri, 1998). Ehri (1998) describes how children who have

not developed robust alphabetic principles have to rely on oral vocabulary knowledge to decode unfamiliar words and remember sight words. For example, when encountering the word *spoon*, without knowing the pronunciation of *oo*, children can correctly pronounce the word *spoon* because they have the letter knowledge of *s*, *p*, and *n* and know *spoon* as a familiar meaning concept.

In a similar vein, children who are learning to read a large number of Chinese characters have to rely on morphemic knowledge to map the sound and shape of the characters, which do not have phonemic representation in the orthography. However, the semantics in lexicon is more complex in Chinese than in English because there are three levels of meaning: lexical (word), morphemic (character), and sub-morphemic (semantic radical). First, the concept of a word in Chinese is fluid. A Chinese word can be one character, two characters, or multiple characters. Overall, the majority of modern Chinese words are compound words that consist of two characters (Packard, 2000). Each character in a compound word can be a transparent morpheme or an opaque morpheme that contributes to the meaning of the compound word to a varying degree (Libben, Gibson, Yoon, & Sandra, 2003). Tan and Perfetti (1997) adapted the triangle model of sound, meaning, and shape connection at the character level. When children have not developed strong morphological awareness, they can rely on their oral vocabulary knowledge to support the connection of the sound and shape. This might be particularly true for Chinese L2 children. In a recent online reading study that investigated Grade 4 MI students' use of strategic decoding and comprehending processes as they were engaged in reading narrative texts, Fortune and Ju (2019) found that less proficient

readers who had not developed strong character knowledge relied on word meaning in decoding Chinese characters and thus could confuse the characters in a word. For example, a reader named the character 毛/mao [*fur*] as 虫/chong [*bug*] because she was familiar with the word 毛毛虫/maomaochong [*caterpillar*].

In addition, the majority of compound characters have a semantic radical which may represent the gist of the character's meaning (Shu et al., 2003). For example, in the same study, Fortune and Ju (2019) also observed that a less proficient reader substituted the character 河/he (river) with 湖/hu (lake) in which both characters share the water radical 氵. The misread here was primed by the water radical shared in many characters relating to the concept of water. For this child who was living in the state of Minnesota, lake is a more familiar, close meaning related to her life experience than river.

What we can learned from these two miscue examples is that the lexical and sub-morphemic knowledge were not sufficient to facilitate the mapping between a character's shape and its corresponding sound and meaning, because the mapping takes place at the character level. Additionally, it is clear from the miscue examples that children may rely on different levels of meaning correctly or incorrectly to connect a character's sound and shape. Within the three constituents of reading (i.e., phonology, orthography, and semantics), one of the major differences between Chinese L1 and L2 children is their size of Chinese vocabulary knowledge and morphemic knowledge. Therefore, it is possible that meaning lexicon may function as the pivotal element in connecting the sounds and shapes of the Chinese characters in words and could contribute to the difference in character learning between Chinese L1 and L2 children.

2.3 Cross-language Transfer in Language and Literacy Acquisition

The theoretical concept of transfer in second language acquisition and biliteracy development has been researched with two main methodologies. The first method is to examine the positive and negative influences on the target language and literacy from L1 language and literacy based on "the similarities and differences between the target language and other languages" (Odlin, 1989, p. 27). The second is to investigate cross-language influences by examining the associations between L1 and L2 reading skills by the researchers who view reading as a constellation of subset skills (Carr & Levy, 1990).

In the first research route on the acquisition of target language and literacy development, Genesee, Geva, Dressler, and Kamil (2006) make a distinction between short-term and long-term transfer from the use of L1 to the learning of the target language and literacy. The analysis on the short-term transfer based on contrasting two linguistic or orthographic systems may represent the "bootstrapping strategy" used by the novice learners to develop target language and literacy in the early stages. The evidence of long-term negative transfer may suggest fossilization in the acquisition of the target language and literacy. Although the longitudinal studies may be more thorough, looking into L2 learners' language and literacy acquisition at certain developmental stages could also provide valuable information for educators. Earlier studies on error analysis observed in a specific developmental window suggest that the differences between L1 and L2 phonology and orthography could explain many L2 spelling errors (Helman & Bear, 2007; James & Klein, 1994; Zutell & Allen, 1988). As Tarone (2005) argues, "[l]earners tend to rely on their native language sound system when they pronounce the

L2" (p. 305). Additionally, Helman and Bear (2007) suggest that L2 learners could experience a developmental delay in spelling mainly due to the insufficient oral language and negative influence from L1 language and literacy knowledge. Therefore, L2 spelling development may depend on a combination of factors, including L2 phonology and L1 phonology and literacy.

In the second methodological route, researchers have evidenced the positive and significant associations in learning to read in two alphabetic languages (e.g., Abu-Rabia & Siegel, 2002; Lindsey, Manis, & Bailey, 2003). A positive correlation was also found in children learning to read Pinyin and English for both native Chinese-speaking and native English-speaking children in the US and in Hong Kong (Lü, 2017; Wang, Perfetti, & Liu, 2005; Zhou, 2012). It is important to note that Zhou (2012) included the separated Pinyin onset-rime spelling and tone identification tasks, and only Pinyin onset-rime spelling were significantly correlated with English real-word reading in non-native Chinese speaking children. These studies suggest that the skills for reading in alphabetic languages are similar and transfer across orthographies. The skill to identify tones seems to be different than spelling in alphabets.

Interestingly, studies on learning to read in Chinese and English show mixed results. Some studies found no correlation between decoding in Chinese and in English for Chinese-English bilingual children who speak Chinese as L1 in English-speaking societies or non-native Chinese-speaking children in Hong Kong (Bialystok, McBride-Chang, & Luk, 2005; Gottardo, Siegel, Yan, & Wade-Woolley, 2001; Pasquarella, Chen, Gottardo, & Geva, 2015; Pasquarella, Chen, Lam, Luo, & Ramirez, 2011; Wang et al.,

2005; Zhou et al., 2017). Three studies that include English foreign language learners in Hong Kong show a strong association between decoding skills in Chinese and in English (Bialystok et al., 2005; Keung & Ho, 2009; Zhou et al., 2017). The discrepancy in the results is unclear, but Bialystok et al. (2005) attribute this strong association between decoding in Chinese and English in their study to the similar or different ways of acquiring knowledge in two languages at certain developmental stages.

The results in previous studies on the correlation between Chinese word reading and Pinyin skills are also mixed in different contexts. In English-speaking schools, neither native nor non-native Chinese-speaking children's Pinyin reading or spelling scores were significantly related to Chinese word reading (Wang et al., 2005; Zhou, 2012). However, for children in MI programs or Chinese L1 programs in mainland China, the Pinyin skill was strongly correlated with Chinese word reading (Ding et al., 2018; Lin et al., 2010; Lü, 2017). It is unknown why the results are different. However, Pinyin spelling skills—the integrated phonological awareness and Pinyin orthographic knowledge—have been interpreted as a measure to gauge or represent phonological awareness (Lin et al., 2010). Because of the causal relationship found between phonological awareness and alphabetic language reading development, this correlation between Pinyin spelling and Chinese word reading has been inappropriately interpreted as evidence to allude to a causal relationship between phonological awareness and Chinese word reading in the studies by using the words *promote* and *facilitate* (Lin et al., 2010, p. 1120; Lü, 2017, p. 307).

Taking the findings from the aforementioned studies, the relationship between reading in Chinese and Pinyin warrants more research conducted in different contexts. It is important to keep in mind that the correlational studies are not sufficient to make causal implications. Further experimental research is also required in the field. The growing body of research on MI students will contribute to the field and make pedagogical innovations on Chinese reading acquisition for young L2 learners of Chinese.

Chapter 3

Understanding the Relationship between Pinyin Spelling Skills and Chinese Word Reading in Elementary Mandarin Immersion Students

3.1 Introduction

Hanyu Pinyin, or Pinyin (meaning *to spell the sounds* in literal translation) is a phonological transcription system that uses alphabet letters and diacritic marks for Mandarin Chinese. Pinyin is usually considered as an aid to teach and learn Chinese characters, rather than an alphabetic orthography. In fact, the Pinyin system and the Chinese characters both represent the same phonological system of Mandarin Chinese. In Mandarin immersion (MI) contexts, English proficient children need to develop second language (L2) Chinese character literacy and first language (L1) English literacy in the first few elementary grades. We usually take it for granted that MI children are emergent as bilingual and biliterate in English and Chinese, but actually Pinyin is the third orthography in their curriculum. To become triliterate, therefore, they have to acquire two phonological systems (i.e., English and Chinese phonological systems) and three orthographies (i.e., English, Chinese, and Pinyin). Researchers and educators have been interested in whether the use of Pinyin can promote the learning of Chinese characters, which is an experimental question. The present study aims to provide an understanding of the relationship between Pinyin spelling and Chinese word reading in young Chinese L2 learners who has English L1 language and literacy background.

3.1.1 Learning the Chinese Characters and the Pinyin System

In the theory of the Universal Grammar of Reading, Perfetti (2003) claims that writing systems encode spoken language and the essential problem of learning to read is to uncover the relationship between one's writing system and the spoken language. To "crack the code" of alphabetic languages (e.g., English and Pinyin), children must understand that letters represent distinct sounds and work out the grapheme-phoneme correspondences within the specific orthographies. In contrast, in learning to read logographic languages (e.g., Chinese characters), children have to uncover that graphic symbols represent the sound and meaning of characters and understand the specific way in which graphic symbols are used to represent syllables and morphemes. Interestingly, spoken Chinese corresponds to two orthographic systems: the Chinese characters and the alphabetic Pinyin system. That is to say, learners have to master the phonological system of spoken Chinese and the two orthographic systems.

The phonological system of Chinese is often referred to as Standard Chinese (SC), Mandarin Chinese, or Putonghua "the common speech" officially used in mainland China, Taiwan, and Singapore. The majority of Chinese words are composed of one- or two-morphemes (Packard, 2000). Each morpheme corresponds to a tonal syllable. Compared to American English (AE), the structure of Chinese syllables is simple. The structure of SC syllable (σ) is traditionally divided into onset and rime without glide. The four possible syllable structures are V, CV, VC, and CVC (Hua & Dodd, 2000). There are no consonant clusters in SC. Each of these syllable-final vowels carries one of the

four possible basic tones, i.e., high level, high rising, falling-rising, and high falling, or a weak tone. The falling-rising tone is often produced as a low tone in real communication.

The primary orthography used in the Chinese-speaking societies is the Chinese characters. The Chinese characters are defined as a morphosyllabic writing system because each character can be a morpheme in a word mapping onto a syllable. The mapping elements in Chinese are enormous in quantity: the 3,500 commonly used Chinese characters and the approximately 400 corresponding Chinese syllables (Anderson & Li, 2006; Anderson, Ku, Li, Chen, & Chen, 2013). According to Hoosain's (1991) analysis of written Chinese, there are about 200 semantic radicals and 800 phonetic radicals. The major radicals can be further divided into about 650 subcomponents (Fu, 1989). The components are formed by strokes, which are the smallest compositional units of the Chinese writing system. Some characters are visually and spatially simple, whereas others are very complex. Chinese characters can be considered an orthographically deep language for two reasons: first is that the phonetics and semantic radicals in compound characters are not reliable enough to cue the sounds or meaning; second, the tone is not represented in any way in the characters (Shu, Chen, Anderson, Wu, & Xuan, 2003).

The alphabetic system that corresponds to Chinese phonology is the Pinyin system. Pinyin uses 26 letters and four diacritics to represent syllables and tones of spoken Chinese. Different from English letters, the Pinyin system adds the letter *ü* and leaves out the letter *v*. According to the *Scheme of the Chinese Phonetic Alphabet*, Pinyin has 21 initials (i.e., consonant phonemes), 35 finals (i.e., vowels which may be followed

by a consonant) and 4 tones (Committee of Chinese Writing System Reform, 1958). Pinyin is considered a fairly transparent orthography. Because the Pinyin initials and finals correspond to the Chinese sounds on the onset and rime level, the majority of them have a one-to-one correspondence. However, the vowels in the finals have one-to-many or many-to-one sound to symbol corresponding relationships (Li & Thompson, 1981). Some of the Pinyin grapheme-phoneme correspondence (GPC) rules overlap with English GPC rules. That is to say, the same letter in English or in Pinyin corresponds to the same sounds in both languages that do not differ greatly in the phonetic features, such as the letters *b*, *p*, *m*, *f*, etc. However, most of the Pinyin finals do not share GPC rules with English (see Study 3 in this dissertation).

3.1.2 Literature Review

To date, three studies have examined the correlational relationships between Pinyin spelling and Chinese word reading. The first study was conducted with Chinese L1 children in mainland China (Lin et al., 2010). The study used a longitudinal design that measured Chinese word reading, syllable deletion, phoneme deletion, Pinyin letter-name knowledge, and Pinyin spelling when students were about six years old (Time 1), and again measured their Chinese word reading one year later (Time 2). The study employed path analysis and evidenced that the predictor variable of Pinyin spelling made a significant and unique contribution to Time 2 Chinese word reading after controlling for Time 1 Chinese word reading, syllable deletion, and age. The second correlational study was a replication of Lin et al. (2010) with L2 learners of Chinese from an early

partial MI program in the US (Lü, 2017). Lü (2017) also found that Pinyin skill was significantly correlated with Chinese word reading and made a significantly unique contribution to Chinese word reading one-year later, above and beyond earlier Chinese word reading knowledge and Chinese phonological awareness. The third study compared the relationships between Chinese word reading and a number of cognitive and metalinguistic skills in native Chinese speaking and non-native Chinese speaking children (Zhou & McBride, 2015). Zhou and McBride (2015) parsed the holistic Pinyin spelling skill into onset-rime spelling and tone identification. They found the contribution of Chinese word reading may only come from tone identification for both Chinese L1 and L2 learners, but onset-rime spelling did not make a unique contribution to Chinese word reading for both groups after controlling for age, nonverbal intelligence, Chinese vocabulary, and Chinese backward digit recall.

First, it is important to note that although the two studies (Lin et al., 2010; Lü, 2017) used a longitudinal design, the correlation between Pinyin spelling and Chinese word reading does not necessarily lend itself to suggest cause and effect between Pinyin spelling proficiency and the learning of Chinese characters. As Fox (2016) suggested, causal interpretation from observational data is risky even with a longitudinal design, because of the potential of leaving out confounding variables. Second, the correlations between Pinyin spelling and Chinese word reading in the three studies were inconsistent. One explanation might be due to the design and the selection of independent variables. Zhou and McBride (2015) included Chinese vocabulary and Chinese backward digit recall without phonological measures, whereas Lin et al. (2010) and Lü (2018) used a

longitudinal design by including Time 1 Chinese character reading and measures for phonological awareness. Another possible explanation to explain the discrepancy in the results was whether the Pinyin skills were treated as a composite skill or two separate skills: Pinyin onset-rime spelling and tone identification. In addition to the inconsistency of the correlational results in these studies, it is still unclear what constructs Pinyin spelling represents in relation to Chinese word reading and other core literacy-related skills for young MI learners.

3.1.3 Research Questions

To understand the correlational relationship between Pinyin spelling and Chinese word reading, the present study asked two research questions. First, to what extent do the composite Pinyin skill and separate Pinyin skills predict Chinese word reading above and beyond a set of literacy related skills based on the current theoretical understandings on Chinese reading acquisition? Second, what is the nature of the relationship between Pinyin skills and Chinese word reading in relation to the identified key literacy-related skills?

3.2 Method

3.2.1 School Setting

Located in a Midwest state of the US, the school is an early total MI program implementing the intensive program model, with approximately 90% of instructional time in Mandarin from kindergarten for all subject matters. From the beginning of Grade

2, students are introduced to English literacy with seven English language arts class periods per week. Students learn simplified Chinese characters from kindergarten. In this school, the Pinyin system is introduced in Chinese language arts at the beginning of Grade 3 for a year. The overall instructional time in Chinese decreases from 75% in Grade 3 to 50% in Grade 4. Chinese language arts and social studies are taught in Mandarin, and English language arts, science, and math in English. Compared to other MI programs, the school sets relatively higher character recognition and production expectations. According to the self-report of the academic director, by Grade 5, students are expected to recognize about 2,000 characters and produce 1,500 characters. All classroom teachers are licensed and are native speakers of the languages in which they teach grade-level content (i.e., either in Mandarin or in English). At the administrative level, one English-speaking principal and one Mandarin-speaking academic director are responsible for executive and academic matters, respectively.

The school has excellent academic performance; the majority of the third graders could meet and exceed academic standards in reading and math in the state standardized assessments in English. The racial composition of the school is mainly White and Asian. Only a small percentage of students receive free or reduced-price lunch or special education services. Although a noticeable proportion of students have Asian backgrounds, the majority of students speak English as their first or dominant language.

3.2.2 Participants

The present study was part of a larger research project that recruited a total of 76 third graders (39 girls and 37 boys; mean age = 9.6 years) at the school. There were 72 students who participated in the study at the beginning of Grade 3. Of these 72 participants, two students did not participate in one of the tasks, so all the data of these two participants were excluded. The majority of the participants had been enrolled in the MI program since kindergarten or Grade 1. Based on the results reported in an earlier study conducted in the MI programs from the same state (Fortune & Song, 2016), most students' Chinese oral language proficiency levels were expected to range in Intermediate levels, using the rating scales and proficiency guidelines that are adapted for young learners and aligned with the American Council on the Teaching of Foreign Languages (ACTFL).

3.2.3 Design

The present study uses an observational design with an aim to examine the correlation between Pinyin spelling and Chinese word reading in Grade 3 MI students. In the study, the response variable was Chinese word reading, and the focal independent variable was Pinyin spelling, which can be separated into two skills: onset and rime spelling and tone identification. To reflect the current theoretical understandings of Chinese character literacy, the present study identified the core subskills related to Chinese literacy development, and the skills to reflect MI students' English literacy acquisition in the learners who were English proficient and had English literacy

instruction. The inclusion of English literacy skills was because Pinyin and English are both alphabetic orthographies and literacy-related competencies, once learned, can be utilized in learning another language (Koda, 2008).

3.2.4 Data Collection

The answers to the research questions in the present study depends on what set of models to build (model specification) and what models to use for inference (model selection). Model specification is defined as *"the determination of which independent variables should be included in or excluded from a regression equation"* (Allen, 1997, p. 166). Model specification is the theoretical considerations for the relationship between independent variables and the dependent variables. Model specification has significant consequences because misspecified models can result in a biased estimation of the parameters of the models, and thus the selected models can influence our interpretation of the relationship between the variables. As Box (1976) noted, "all models are wrong" (p. 792), meaning all statistical models do not represent the reality in the real world and have some specification errors. However, he also acknowledged that some models are useful approximations for us to understand the real world. Therefore, it is important to select the well-specified models, meaning to choose the variables that are supported by the current theoretical accounts for inferences.

According to McBride and Wang (2015), the metacognitive core skills for Chinese reading acquisition include phonological awareness, morphological awareness, and visual-orthographic abilities. In this paper, two aspects of metalinguistic awareness—

phonological and orthographic awareness—together with oral vocabulary knowledge were selected as the key variables related to Chinese reading. The present study did not include morphological awareness for three reasons. First, the MI students in the participating schools are usually introduced to words as holistic meaning concepts, instead of providing explanations of the characters' meaning. Second, morphological awareness tasks can be confounded by students' listening comprehension. In Zhou's (2012) dissertation study, the Chinese L2 participants hardly understood the instructions for the task. Third, character level and sub-character level morphological awareness makes contributions to Chinese word reading through the mediation of Chinese vocabulary (Tong et al., 2017). Therefore, replacing morphological awareness with Chinese vocabulary could be appropriate. In addition to these independent variables that were related to Chinese character literacy, the MI students' English literacy measures were also included because, as discussed above, these students were English speaking children who had received L1 English literacy at Grade 2, and English and Pinyin are both alphabetic orthographies that may have cross-language influences. The first variable related to English literacy was the English nonword spelling. Second was a measure to tap into their ability to describe Chinese sounds before they were introduced to Pinyin symbols. The measures are described as follows.

Chinese Phonological Awareness

The most researched metalinguistic awareness in relationship to alphabetic word reading and Chinese word reading is the phonological awareness (e.g., Liberman,

Shankweiler, Fischer, & Carter, 1974; Shu et al., 2008). The measure tapped into children's ability to identify and manipulate the sound properties in Chinese. Syllable and onset-rime levels of phonological awareness were found to be significantly associated with Chinese word reading in a number of studies with young Chinese L1 and L2 children (e.g., Ho & Bryant, 1997a; Lü, 2017). In addition, this ability, once acquired, can transfer to learning another language (e.g., Bialystok et al., 2005).

The task included 5 items of syllable deletion and 15 items of the syllable-initial phoneme deletion section, adapted from Zhou and McBride (2015). The total score of the task was 20. If a child failed to name 10 item words consecutively, the testing was stopped. The task was administered individually by trained research assistants.

Chinese Orthographic Memory and Delayed Copying

Earlier studies have found that character orthographic knowledge and skills play a significant role in learning to read Chinese, because Chinese learners need to develop knowledge and skills to remember and distinguish large quantities of visually-spatially complex components (Guan, Liu, Chan, Ye, & Perfetti, 2011; Tan, Spinks, Eden, Perfetti, & Siok, 2005; Wong, 2018; Y. Zhou & McBride, 2015). Zhou and McBride (2015) found that the skill to hold a character's component in memory and selecting the character with the component was significantly higher in Chinese L1 children than Chinese L2 children, and this skill made a significantly unique contribution to Chinese word reading for Chinese L1 and L2 children. Additionally, Tan and his associates (2005) found that

writing is strongly associated with reading in learning Chinese for Chinese L1 children and claimed that reading in Chinese depends on writing.

Chinese orthographic awareness was tested with two tasks. The first one is visual orthographic memory adapted from the measure used in Zhou and McBride (2015) to tap children's receptive knowledge of Chinese character components. This task included 36 real character components as stimuli that were embedded in one of the four real look-alike characters as four options. Participants were asked to view a stimuli component presented on an easel display stand for 3 seconds, and then searched for one character out of four that contained the component. Each correct response was rewarded 1 point, for 36 points in total. The task was administered in groups of four to six students with paper and pencil.

The second task tapped students' productive orthographic skill and short-term memory of unfamiliar characters by their writing. Participants were asked to view a character for 5 seconds, and then write down the character. Each character can be divided into two components, each worth 1 point. The correct position of the two components was also awarded 1 point. The possible total score for each character was 3 points. There were 6 characters in the task for a total score of 18. The task was administered in groups of four to six students with paper and pencil.

Chinese Oral Vocabulary Knowledge

Oral vocabulary knowledge in a person's mother tongue is acquired before they learn to read, but oral vocabulary knowledge and literacy acquisition usually develop

simultaneously for L2 learners. Oral vocabulary knowledge is important in learning to read Chinese. As Evenson (1998) reported, recognizing a word and decoding its meaning were strongly correlated in L2 adult learners of Chinese. Tong, Tong, and McBride (2017) reported that vocabulary knowledge partially moderated the correlations of the lexical level and fully mediated the sublexical level of morphological awareness with Chinese word reading in Chinese L1 children. In Zhou and McBride (2015), Chinese L1 children performed significantly better than Chinese L2 children in Chinese vocabulary knowledge, which made a unique and significant contribution to Chinese word reading for both groups of children.

The Chinese oral vocabulary knowledge task was adapted from the Peabody Pictures Vocabulary Test-4 (Dunn & Dunn, 2007) and the Expressive Vocabulary Test-2 (Williams, 2007) to test the children's receptive and expressive vocabulary knowledge in Chinese. Students' classroom teachers were consulted before the items were chosen from their textbooks or storybooks. In the receptive vocabulary section (45 items), children were asked to listen to a Chinese word orally presented by the examiner and point to one of the four pictures indicating the meaning of the word they heard. In the expressive vocabulary section (15 items), children were asked to name the objects or describe people's actions or emotions in the picture. If a child failed to name 10 item words consecutively, the testing was stopped. The task was administered individually by trained research assistants. Each item was worth 1 point. The total score of the measure was 60.

Invented Spelling-Eng

This measure was created to tap into Grade 3 students' ability to represent the Chinese sounds using English letters before Pinyin instruction at the beginning of Grade 3. This measure expanded the task of Pinyin invented spelling used in Zhou and McBride (2015) by including 20 two- or three-syllable words or nonwords (see Appendix B). The total number of syllables in the task were 41, including 19 unique SC consonants (17 syllable-initial consonants), 3 unique SC glides, 16 unique vowels at least once (see Appendix C). The students were not asked to identify tones because they had not been taught tones in their classes at the time of data collection. Children were asked to listen to the syllables twice and use their English letter-sound knowledge to spell. The task was administered to a group of four to six students with paper and pencil.

The answer keys (see Appendix C) were developed to judge whether or not the English spelling students used to describe the Chinese phonemes was close enough. To create the answer keys, equivalents and approximations between Chinese and American English sounds were identified. This decision was made by triangulating three sources of data that included the third graders' frequent use of English spelling in this task, their frequent sound substitutions in articulation for the target Chinese sounds (see Study 3 in this dissertation), and the analysis of the phonetic features of AE and SC. The three phonetic features for consonants were the following: place of articulation, manner of articulation, and voice onset time, and for vowels and glides they were the degree of openness, tongue position, and lip roundedness (Lin, 2007). Next, the possible English letters corresponding to the AE phonemes that were the equivalencies and

approximations for the Chinese phonemes were identified. Because English is not a transparent orthography, the common spelling letters for a phoneme were considered. In most cases, the letter-sound correspondence was considered on the basis of each individual letter for each phonological segment, except the cases where multiple letters could represent a phoneme (e.g., *ou* for [au]), or multiple letters could represent the same phoneme. For example, some students used both the letter *i* that corresponds to the high front vowel [ɪ] and the letter *u* for the high back rounded vowel [u] to represent the Chinese-specific high front rounded vowel [y]. The response was coded separately for onset (1 point) and rime (1 point). For each syllable the possible total score was 2 points. The total possible score for 41 syllables in the task was 82.

Pinyin Spelling

The focal independent variable was Pinyin spelling, which aimed to assess students' ability to spell Chinese sounds using Pinyin initials and finals and diacritic marks to represent tones. The same set of syllables in Invented Spelling-Eng was used in Pinyin spelling when the students had learned Pinyin for almost one academic year. This measure included 17 unique Pinyin initials and 35 finals. Because Pinyin spelling is a composite skill of initial and final spelling and tone identification, the scores of Pinyin initial and final spelling and tone identification were calculated separately. Additionally, the separate scores were also added to make a holistic score of Pinyin spelling. The total score of Pinyin initial and final spelling were 82 and the total score for tone identification

was 42, respectively, and the total score of the holistic Pinyin spelling was 124. The task was administered in groups of four to six students with paper and pencil.

English Nonword Spelling

Another variable that may confound Pinyin spelling and Chinese word reading was children's English grapheme-to-phoneme correspondence knowledge. English nonword was used because it ruled out the influence of familiar word spelling knowledge. Participants listened to the English nonwords from a recording of an adult female native English speaker. This task was adapted from Campbell (1985) and coding was based on the possible spellings provided in the study. Each nonword has only one syllable. The correct spelling of each onset or rime in the syllable was awarded 1 point. Each nonword was worth 2 points. There were 15 items in the task, and the possible total score was 30. The task was administered in groups of four to six students with paper and pencil.

Chinese Word Reading

The dependent variable reflected students' character literacy outcome captured through Chinese word reading. The Chinese word reading task included single-character (20 items) and two-character (60 items) Chinese words. These words were chosen from children's Chinese textbooks and storybooks. Children were asked to name each word presented on an easel display stand. Scores were based on the number of characters they named correctly. The total score for this task was 80. If a child failed to recognize 10

item words consecutively, the testing was stopped. The task was administered individually by trained research assistants.

Control Variables

Other control variables included age and non-verbal intelligence. Student ages were converted to a numeric value by year. Raven's Coloured Progressive Matrices A was used to assess children's clear-thinking abilities (Raven, 1998). There were 36 items in the test. Each item was worth 1 point and the possible total score of the task was 36. The task was administered in groups of four to six students with paper and pencil.

3.2.5 Data Analysis

Descriptive analyses were first carried out to identify patterns of the variables. Next, hierarchical linear regression analyses were performed to characterize the extent of Pinyin spelling associated with Chinese word reading in relation to the identified independent variables. The assumptions of normality, homoscedasticity, and multicollinearity for the statistical models were examined to check if the models are good fit with normally distributed residuals, homogeneous variances, and low variance inflation.

3.3 Results

3.3.1 Descriptive Analyses

Descriptive statistics and internal consistency results (Cronbach's α) of the variables were reported in Table 3.1. All measures of internal consistency, except Raven's non-verbal intelligence and orthographic memory, were above satisfactory reliability levels (≥ .70). The correlations between each variable were calculated and reported in Table 3.2.

Chinese word reading has a statistically significant correlation with the variables that tapped into Chinese phonological awareness, Chinese vocabulary knowledge, separate Pinyin spelling skills and holistic Pinyin spelling, Invented Spelling-Eng, but not with English nonword spelling, the two Chinese orthographic awareness measures, or control variables. These two variables that tapped into orthographic awareness were only significantly correlated with each other.

The separate Pinyin skills (i.e., Pinyin onset-rime spelling and tone identification) and the holistic Pinyin spelling were significantly correlated with each other. Pinyin onset-rime spelling was also significantly associated with English nonword spelling, Invented Spelling-Eng, and Chinese phonological awareness, but not with Chinese vocabulary. On the contrary, tone identification was significantly correlated with Chinese vocabulary knowledge, but not with English nonword spelling. Additionally, Chinese vocabulary knowledge was found to have statistically significant correlations with Chinese phonological awareness. Last, Invented Spelling-Eng was significantly

associated with both composite Pinyin skill and the separate Pinyin skills, Chinese phonological awareness, and English nonword spelling.

Table 3.1 *Descriptive Results of the Variables (N = 70)*

Variable	Total Score	Cronbach's α	*M*	*SD*	*Min.*	*Max.*
Age			9.66	0.33	9.2	10.3
Raven's	36	.59	31.46	2.67	25	36
VOC	60	.76	49.32	5.07	31	59
Copy	18	.71	12.77	3.36	3	18
OM	36	.58	28.37	3.59	20	35
PA	20	.86	14.40	3.62	5	19
Invented	82	.84	67.68	8.11	49	81
PY.OR	82	.93	51.93	13.73	17	77
Tone	41	.86	25.42	7.21	9	36
PY	123	.95	77.35	19.29	31	109
ENG	30	.71	22.41	3.70	12	29
CWR	80	.92	51.83	12.46	9	73

$^{*}p \leq 0.05$. $^{**}p \leq 0.01$. $^{***}p \leq 0.001$.

Note. Age = age in year, Raven's = Nonverbal intelligence, VOC = Chinese vocabulary, Copy = Delayed copying, OM = Character orthographic memory, PA = Chinese phonological awareness, Invented = Invented Spelling-Eng, PY.OR = Pinyin onset and rime spelling, Tone = Pinyin tone identification, PY = Pinyin spelling, ENG = English nonword spelling, CWR = Chinese word reading.

Table 3.2 *Intercorrelations between Pinyin Literacy and Character Literacy Related Variables (N = 70)*

Measure	Age	Raven's	VOC	Copy	OM	PA	Invented	PY.OR	Tone	PY	ENG	CWR
Age	—											
Raven's	.00	—										
VOC	.14	.29*	—									
Copy	.13	.26*	.08	—								
OM	.10	.29*	.16	.39***	—							
PA	.08	.33**	.38**	.06	.15	—						
Invented	.29*	.22	.13	.01	.18	.32**	—					
PY.OR	.21	.20	.08	.10	.10	.30*	.53***	—				
Tone	.17	.14	.39***	.07	.03	.43***	.26*	.65***	—			
PY	.22*	.20	.20	.10	.09	.39**	.48***	.96***	.84***	—		
ENG	.05	.22	.12	-.10	.04	.33**	.50***	.35**	.17	.32**	—	
CWR	.12	.22	.59***	.22	.16	.41***	.25*	.48***	.59***	.56***	.22	—

*$p \leq 0.05$. **$p \leq 0.01$. ***$p \leq 0.001$.

Note. Age = age in year, Raven's = Nonverbal intelligence, VOC = Chinese vocabulary, Copy = Delayed copying, OM = Character orthographic memory, PA = Chinese phonological awareness, Invented = Invented Spelling-Eng, PY.OR = Pinyin onset and rime spelling, Tone = Pinyin tone identification, PY = Pinyin spelling, ENG = English nonword spelling, CWR = Chinese word reading.

3.3.2 Hierarchical Linear Regression Analyses

The hierarchical linear regression was used to examine whether Pinyin spellings can predict Chinese word reading above and beyond the other key skills that were identified to be associated with character literacy and Pinyin literacy development for the MI students. In addition, the hierarchical linear regression analyses can help us understand the relationships between Pinyin skills and Chinese word reading in relation to other identified key variables.

Because the focal independent variables of composite and separate Pinyin skills, together with three independent variables (i.e., Chinese phonological awareness, Invented Spelling-Eng, and Chinese vocabulary), were significantly associated with Chinese word reading, four sets of hierarchical linear regression analysis were performed and reported in Table 3.3. In Model 1, the Chinese phonological awareness, Invented Spelling-Eng, and Chinese vocabulary were first entered as the independent variables. The goal of this analysis was to estimate the contribution of the independent variables without Pinyin skills to Chinese word reading. As shown in Model 1, the three variables together explained 40% ($p < .001$) of variance in Chinese word reading. Only Chinese vocabulary made a significant contribution ($p < .001$) to Chinese word reading above and beyond Chinese phonological awareness and Invented Spelling-Eng. Because the correlation between Chinese vocabulary and Chinese word reading is $r = .59$ ($p < .001$), the variance of Chinese word reading explained by Chinese vocabulary is 34%. Including invented Spelling-Eng and Chinese phonological awareness accounts for an additional 6% of variance, but this additional variance is only approaching to statistically significant (p

= .05). In addition, the unique variance (partial eta square) accounted for by Chinese vocabulary was 21%. As shown in Table 3.2, Chinese vocabulary was significantly correlated with Chinese phonological awareness (r = .38, p < .01) and with Chinese word reading (r = .59, p < .001), and the correlation between Chinese phonological awareness and Chinese word reading was .41 (p < .001). Because the regression coefficient for Chinese phonological awareness was not statistically significant in Model 1, this suggests that the variance in Chinese word reading accounted for by Chinese phonological awareness was primarily shared with and accounted for by Chinese vocabulary.

Similarly, Chinese phonological awareness was significantly correlated with Invented Spelling-Eng (r = .32, p < .01). Invented Spelling-Eng was significantly correlated with Chinese word reading (r = .25, p < .05), but not with Chinese vocabulary (r = .13, p = .30). Because the regression coefficients for Invented Spelling-Eng was not statistically significant in Model 1, this suggests that the variance in Chinese word reading accounted for by Invented Spelling-Eng was mainly shared with and explained by Chinese phonological awareness.

In the second model, the focal independent variable of holistic Pinyin scores was added as the fifth independent variable to examine if the composite Pinyin skill can predict Chinese word reading above and beyond the four independent variables in Model 1. The total variance accounted for by all five predictors to Chinese word reading in Model 2 was 56%, with an increase of 16 percentage points over the R^2 value of Model 1. Additionally, the Pinyin skill and Chinese vocabulary were both statistically significant

predictors, and the unique variances from the composite Pinyin skill and Chinese vocabulary were 16% and 19%, respectively.

The third model separated the composite Pinyin skill into onset-rime spelling and tone identification. The total variance explained by all five predictors remained the same as Model 2 (R^2 = 56%, $p < .001$), but only Chinese vocabulary and Pinyin onset-rime spelling made unique and significant contributions to Chinese word reading, with each predictor explaining 16% and 5% of variance in Chinese word reading.

To compute the variance explained solely by Pinyin onset-rime spelling and Chinese vocabulary to Chinese word reading, a reduced model, Model 4, with only onset-rime spelling and Chinese vocabulary as the independent variables was created. The total R^2 value of the reduced model was 53%, with onset-rime spelling and Chinese vocabulary each accounting for 19% and 30% of variance in Chinese word reading.

Model checking on the assumptions of normality and homoscedasticity of all three models were not violated (see Appendix D). The multicollinearity of the models was tested, and the variance inflation factors (VIF) for all variables were below 3, which was considered small (see Table 3.3).

Table 3.3 *Results of Hierarchical Linear Regression Models Predicting Chinese Word Reading (N =70)*

	Model 1	Model 2	Model 3	Model 4
Invented	0.20 (0.16)	-0.09 (0.15)	-0.10 (0.16)	
PA	0.63 (0.37)	0.25 (0.33)	0.26 (0.34)	
VOC	1.23 (0.26)***	1.16 (0.22)***	1.18 (0.24)***	1.36 (0.21)***
PY		0.31 (0.07)***		
PY.OR			0.33 (0.13)**	0.42 (0.08)***
Tone			0.27 (0.22)	
Constant	-31.87 (14.85)*	-27.51 (12.92)*	-27.79 (13.10)	-37.25 (10.80)**
df	66	65	64	67
F Statistic	9.90	8.58	8.65	8.66
R^2	0.40***	0.56***	0.56***	.53***

*$p \leq 0.05$. **$p \leq 0.01$. ***$p \leq 0.001$.
Note. Values represent unstandardized coefficients and values in parentheses represent standard errors. Invented = Invented Spelling-Eng, PA = Chinese phonological awareness, VOC = Chinese vocabulary, PY = Pinyin spelling, PY.OR = Pinyin onset-rime spelling, Tone = Pinyin tone identification.
Model 1: VIF(Invented) = 1.11, VIF(PA) = 1.28, VIF(VOC) = 1.17.
Model 2: VIF(Invented) = 1.33, VIF(PA) = 1.36, VIF(VOC) = 1.18, VIF(PY) =1.41,
Model 3: VIF(Invented) = 1.53, VIF(PA) = 1.39, VIF(VOC) = 1.39, VIF(PY.OR) = 2.51, VIF(Tone) = 2.35
Model 4: VIF(VOC) = 1.01, VIF(PY.OR) = 1.01.

3.4 Discussion

The primary purpose of the present study was to investigate the extent to which Pinyin spellings predict Chinese word reading. In Model 2, adding the composite Pinyin skill to Model 1 increased the R^2 value by 16 percentage points. In Model 3 and 4, the Pinyin onset-rime spelling explained 4% and 17% of unique variance in Chinese word reading, respectively. The findings suggested that the composite Pinyin skill and the Pinyin onset-rime spelling skill were statistically significant predictors to explain third-grade MI students' Chinese word reading above and beyond a set of key Chinese literacy and Pinyin literacy related variables. The results were consistent with earlier studies on Chinese L1 and Chinese L2 students that Pinyin spelling can predict Chinese word reading (Lin et al., 2010; Lü, 2017).

Another purpose of the study was to understand the relationship between Pinyin skills and Chinese word reading in MI students in relation to other identified literacy-related skills. A Pinyin speller needs to identify the phonological elements in a Chinese syllable and be able to use the corresponding Pinyin initials and finals together with tone marks to represent the phonological elements. Pinyin onset-rime spelling requires the integrated skill of phonological awareness and orthographic knowledge. Tone identification requires the learners to recognize the tones and use the corresponding diacritic marks to represent the tones. These two separate skills are both strongly correlated with composite Pinyin skill, suggesting that these two skills tap into the similar phonological sensitivity to the Chinese sounds. The present study used two models to display the relationships among composite and separate Pinyin skills, Chinese

phonological awareness, Invented Spelling-Eng, and Chinese vocabulary in association with Chinese word reading.

It is important to note that, in Model 1, only Chinese vocabulary was a statistically significant predictor of Chinese word reading after controlling for Chinese phonological awareness and Invented Spelling-Eng. In other words, the ability to identify Chinese sounds tested in Chinese phonological awareness and Invented Spelling-Eng, which is required in Chinese word reading, may be captured by the measure of Chinese vocabulary. Additionally, Chinese phonological awareness is significantly correlated with Chinese vocabulary and English nonword spelling. This suggests that the measure of Chinese phonological awareness tapping into learners' syllable awareness and onset-rime awareness can be an effect of Chinese oral vocabulary growth (e.g., Goswami, 2001; Metsala, 1999) or transferred from L1 English (Wang, Perfetti, & Liu, 2005).

Although adding either the composite Pinyin skill or the separate Pinyin skills increased the R^2 value by 16 percentage points compared to Model 1, Model 3 indicates that only onset-rime spelling, not tone identification, was the significant predictor above and beyond Chinese phonological awareness, Invented Spelling-Eng, English nonword spelling, Chinese vocabulary, and tone identification. Because both of the separate skills are strongly correlated with composite Pinyin skill, the unique variance in Chinese word reading explained by the composite Pinyin skill in Model 2 was shared by tone identification and onset-rime spelling in Model 3. More importantly, the two separate Pinyin measures have a moderate to strong correlation with each other, so they share a large amount of variance in common. This suggests that once one separate Pinyin skill is

in the model, it likely accounts for most of the variance in Chinese word reading that is accounted for by the other skill.

For tone identification, it was significantly related to Chinese word reading and Chinese vocabulary knowledge. When tone identification was entered separately with Pinyin onset-rime spelling in Model 3, the regression coefficient of tone identification was not statistically significant, indicating that the skill to identify tones measured by tone identification that is related to Chinese word reading can be partially accounted for by Chinese vocabulary and by onset-rime spelling. This may suggest the sensitivity to tones is also required in Chinese vocabulary knowledge or in identifying the onset and rimes in Chinese sounds. Additionally, as suggested in Models 3 and 4, the unique variance of Chinese word reading explained by Pinyin onset-rime spelling is largely shared with tone identification in Model 3. This explains when removing tone identification in Model 4, the unique variance of Pinyin onset-rime spelling increased noticeably. In all, Pinyin onset-rime spelling made a significantly unique contribution to Chinese word reading, suggesting that the skill to spell onset and rime with Pinyin letters requires the skill above and beyond the identified variables measured.

The four models together suggest that the largest contribution to Chinese word reading came from Chinese vocabulary. It is consistent with earlier studies on adult Chinese L1 and L2 learners that recognizing Chinese words is strongly associated with the knowing the words' meaning (Everson, 1998; Jiang, 2003; Zhao, 2003). That is to say, oral vocabulary knowledge plays an important role in Chinese word reading. As argued in Ouellette (2006), meaning can interact with the mapping of orthography and

phonology in irregularly spelled words that do not have a transparent grapheme-phoneme correspondence. Because the Chinese orthography doesn't have symbol to sound correspondence at phonemic level, storing and retrieving sounds from orthographic representations may depend on meaning, as demonstrated in Seidenberg and McClelland's (1989) triangle model. Additionally, lexical morphological awareness contributes to Chinese word reading via the mediation of Chinese oral vocabulary (Tong et al., 2017), because most of the Chinese words are two-character words and each character can be a transparent or an opaque component contributing to the meaning of the whole word. Therefore, it is important to include morphological awareness or oral vocabulary knowledge in studies on Chinese word reading. With regard to the shared variance between Chinese vocabulary knowledge and Pinyin onset-rime spelling, it suggests that Chinese vocabulary captures the phonological awareness that is related to Chinese word reading and Pinyin onset-rime spelling requires the ability to identify the phonological elements.

Regarding the effect of onset-rime spelling on Chinese word reading, the findings from this study are different from Zhou and McBride (2015) who found that Pinyin onset-rime spelling did not make contribution to Chinese word reading but the tone identification did for both Chinese L1 and L2 children. This difference in the results between the present study and Zhou et al. (2015) may be due to the students' characteristics and educational experiences. One of the most important differences that can be attributable to the effect is the different developmental stages the students were tested at. In their study, the students had been introduced Pinyin for four years, and both

native and nonnative Chinese speaking students were fairly proficient at Pinyin spelling and they did not differ in onset-rime spelling proficiency. However, in the present study, this group of third grade MI students had only been taught to Pinyin for less than an academic year.

The unique contribution of Pinyin onset-rime spelling to Chinese word reading may be confounded by other factors that were not included in the present study. As suggested in Bernhardt's (2011) second-language reading framework, the unexplained variances in L2 reading performance may come from social, cognitive, sociocognitive dimension. Because this study only included two metalinguistic, one linguistic construct and English spelling related measures, it is possible that this unique contribution in Chinese word reading from Pinyin onset-rime spelling can be accounted for by other cognitive constructs, such as the rapid automatized naming (RAN) that requires the retrieval of the visual print as a core construct identified in learning alphabetic orthographies and the Chinese characters (McBride & Wang, 2015).

Another possible explanation is that these young MI students learn two sets of orthographic knowledge of Chinese from the same Chinese language art classes with similar learning strategies and instructional methods. These MI students were taught to pair Pinyin symbols and their corresponding sounds using a number of activities, particularly repetitions and choral reading. These activities were in some way similar to the way they were taught to learn the Chinese characters. The ability to map thousands of Chinese characters to the corresponding syllables is also required in pairing sounds and 21 Pinyin initials and 35 Pinyin finals. This visual-verbal paired association learning

(PAL) for young learners (Li, Shu, McBride-Chang, Liu, & Xue, 2009; Litt & Nation, 2014), which is independent from Chinese phonological awareness and Chinese vocabulary, is critical in learning to read and spell Pinyin initials and finals and Chinese characters. Earlier research also found a strong correlation between decoding two typologically different orthographies, (i.e., Chinese characters and English) in Chinese L1 students who would use similar learning strategies to learn Chinese and English (Bialystok et al., 2005; Keung & Ho, 2009; Zhou et al., 2017).

Another important finding in the present study was that Chinese phonological awareness was strongly associated with English, Pinyin, and Chinese character related skills. The findings add more evidence to the current literature (Bialystok et al., 2005; Wang et al., 2005) suggesting that phonological awareness is a general metacognitive skill and, once learned, can be transferred across learning other orthographies, in this case, the Chinese characters, Pinyin, and English. Additionally, there were strong associations between Chinese phonological awareness, holistic Pinyin spelling, onset-rime spelling, and tone identification in young Chinese L2 learners. The contribution of Chinese phonological awareness to Chinese word reading was fully mediated by Chinese vocabulary and the composite Pinyin skill. This finding suggest that Pinyin spelling has the potential to gauge Chinese phonological awareness for L2 learners as indicated in previous studies conducted with Chinese L1 children (Ding et al., 2015).

Additionally, the present study created the measure of Invented Spelling-Eng to capture the ability of describing Chinese phonemes using English letters before the students were introduced to Pinyin. This measure reflects two distinct skills: Chinese

phonological awareness and English letter-sound correspondence skill. As shown in Table 3.2, this measure was significantly related to Chinese phonological awareness and English nonword spelling. On the other hand, the association between Invented Spelling-Eng and Chinese word reading had less magnitude than it had with Chinese phonological awareness or English nonword spelling. Therefore, it suggests the relationship between this measure, combined the two distinct skills of Chinese phonological awareness and English spelling, and Chinese word reading can be confounded by Chinese phonological awareness and English nonword spelling.

Lastly, the two measures that tap into Chinese orthographic knowledge, delayed copying and orthographic memory, did not correlate with Chinese word reading. This finding was also consistent with L2 reading research in Zhou et al. (2017), again indicating that pure orthographic knowledge is not sufficient in learning to read Chinese characters given the fact that these MI students had had considerable character writing practice in their classes for three years. Therefore, one suggestion to teachers may be to add orthographic practice into meaningful character learning activities.

3.5 Conclusions

The present study found that both composite Pinyin spelling, together with Chinese vocabulary, significantly explained unique variance of Chinese word reading for Grade 3 students in early total MI programs. In other words, Pinyin spelling skills were a composite skill of onset-rime spelling and tone identification that made a major contribution to examining Chinese word reading performance above and beyond the

Chinese phonological awareness, Chinese vocabulary knowledge, and the spelling skill using English letter before the MI students were taught Pinyin. It was also found that Pinyin onset-rime spelling skill—mapping Pinyin letters to Chinese sounds—exhibits a unique contribution to Chinese word reading after controlling for a set of character literacy and Pinyin literacy related variables.

Earlier research has evidenced that Pinyin activities can promote Chinese phonological awareness (Xu & Ren, 2004). Although phonological awareness has been found to be correlational and causally related with reading in alphabetic languages (e.g., Goswami & Bryant, 1992), this causal link has not been established in Chinese reading acquisition (McBride & Wang, 2015; Zhou et al., 2012). Therefore, it is inappropriate to interpret the correlation between Pinyin spelling and Chinese word reading for causation. The unanswered question here is whether phonological training could promote Chinese word reading for L1 and L2 learners of Chinese, which still remains on the research agenda on the Chinese L1 and L2 learners, especially for Chinese L2 learners who have alphabetic language background. Future experimental studies on this causal link between phonological awareness and Chinese word reading are needed with Chinese L1 and Chinese L2 children.

Chapter 4

Does Alphabetic Pinyin Facilitate or Hinder the Learning of Chinese Words in Meaningful Reading Activities? Evidence from Early Total Mandarin Immersion Students

4.1 Introduction

Hanyu Pinyin, or Pinyin (to spell the sound in literal translation), is an alphabetic orthography using 26 Latin letters and four diacritic marks to represent syllables and tones of spoken Mandarin Chinese. Because the Chinese characters do not have transparent phonemic sound-symbol correspondence, Pinyin is widely used as a sound transcription system for Chinese first language (L1) children to learn Chinese characters in mainland China (Huang & Liao, 2007). Additionally, Pinyin input is the predominant typing method on digital devices. In Taiwan, the counterpart phonological transcription system is Zhuyin fuhao. Pinyin is usually introduced to second language (L2) adult learners to access to spoken Mandarin Chinese and to learn the Chinese characters in college-level courses (Ye, 2013). In early total or early partial MI programs, Pinyin instruction begins either at Grade 1, Grade 2, or Grade 3. Some researchers believe that Pinyin should be introduced to MI students earlier rather than later, while other researchers and MI educators posit that late Pinyin introduction may be a better approach. The focus of this debate is whether the use of Pinyin in reading materials activities can facilitate Chinese character learning for Chinese L2 young learners. This has been a

practical and theoretical issue that matters to thousands of students in over 200 elementary MI programs in the US (Mandarin Immersion Parents Council, 2019).

In North America, MI is a newcomer to the immersion education but is developing at a fast pace in the last decade. The majority of the MI programs in the US are early partial programs, where students learn school subject matters in Chinese for half of the elementary school day and in English for the other half since kindergarten. In some MI programs, however, the instructional time in Chinese for the first few schooling years is 90 percent, which are characterized as early total MI programs. Although the program models vary, the goals for all MI programs remain the same—to achieve academic success, attain high level of bilingualism and biliteracy, and cultivate high sensitivity to the target culture (Howard & Christian, 2002). However, recent studies have found that MI students' Chinese reading score was rated the lowest among the four skill areas of listening, speaking, reading, and writing (Burkhauser et al., 2016; Fortune & Song, 2016; Watzinger-Tharp et al., 2018). MI students on average were about two sub-levels lower in Chinese reading than their peers who were enrolled in alphabetic immersion programs. The low performance in reading has raised concerns among stakeholders because if these children are at novice levels in reading, they are not able to learn complex school subject matters in Chinese through text. Obviously, character literacy is a challenge for MI students who have alphabetic language background, but the research to support Chinese L2 children has been sparse. Would the use of alphabetic Pinyin facilitate the learning of Chinese characters for MI students? This study aims to explore the causal relationship between the use of Pinyin and the learning of Chinese in early total MI students.

4.1.1 Theoretical Issues on Chinese Reading Acquisition

To discuss Chinese reading acquisition, it is necessary to compare with the theories on the most researched English reading acquisition. Phonology-based reading theories suggest that learning to read in alphabetic languages for children is to acquire the letter-sound correspondence rules. Additionally, the simple view of reading in English suggests that word recognition, that is, knowing the English letter-sound correspondence rules, and knowing the meaning are independent (Gough & Tunmer, 1986). Uncovering English alphabetic principles requires corresponding 70 graphemes (including 26 letters and the letter combinations) to about 40 phonemes (Ehri, 1998). Once the learners master the alphabetic principle, the element of meaning is not necessary in the activation of the sound, such as sounding out nonwords. Because English words can have complex syllable structures (such as the word *strengths*) and one word can be multisyllabic, the most researched subset skill in English word recognition is phonological awareness—the ability to reflect and manipulate the sound units of one's spoken language (Nagy & Anderson, 1999). Over the past half century, researchers have evidenced the correlational and causal relationships between phonological awareness and English word reading (see a detailed review in Rayner et al., 2001).

In modern Chinese, the majority of words are composed of two characters; each character corresponds to a syllable. Compared to English, Chinese syllable structures are simpler—there are only four possible consonant (C) and vowel (V) combinations in a syllable: V, CV, VC, and CVC (Hua & Dodd, 2000). Chinese is a tonal language; each syllable bears one of the four possible tones that are distinct by the pitch contours of our

voice (i.e., high-high, mid-high, low-high/low, and high-low) or a weak tone. In studies on learning to read in Chinese, phonological awareness at different levels was shown to be correlated with Chinese word reading in Chinese L1 children (e.g., Ho & Bryant, 1997a; Shu et al., 2008). It was also found that Pinyin instruction improved Chinese phonological awareness for Chinese L1 kindergarteners at onset and rime awareness after one-year of Pinyin learning (Ren & Xu, 2004). In addition, Pinyin spelling, the integration of phonological awareness and orthographic knowledge of Pinyin letters, was argued to be a valid measure to gauge phonological awareness (Ding et al., 2015), and Pinyin spelling was found as a long-term predictor of Chinese word reading in Chinese L1 and Chinese L2 learners (Lin et al., 2010; Lü, 2017). However, no evidence thus far suggests a causal relationship between phonological awareness and Chinese word reading (McBride & Wang, 2015; Zhou et al., 2012). That is to say, it is unclear if phonological training can improve Chinese word reading for Chinese L1 and L2 readers. Therefore, it is also unknown if increased Chinese phonological awareness, promoted by Pinyin training, can be reflected as an advantage in Chinese word reading.

In learning to read in Chinese, children need to learn the correspondence between about 3,500 commonly used characters and 1,200 possible tonal syllables (Anderson, Ku, Li, Chen, Wu, et al., 2013; Anderson & Li, 2006). If this mapping task were pure one-on-one syllable to character pair association, it would be an impossible, daunting task for young learners. According to Seidenberg and McClelland's (1989) triangle framework, storing and retrieving sounds from orthographic representations can go through the route via semantics. In fact, emergent English readers may rely on their oral vocabulary

knowledge to figure out irregular spelling and sound varieties in English words (Ehri, 1998). The function of meaning is important in the mapping of orthography to phonology when the orthography is opaque (Ouellette, 2006). The Chinese characters do not have phonemic level sound to symbol correspondence, and there are three levels of meaning embedded in Chinese words: lexical (word), morphemic (character), and sub-morphemic (semantic radical). Meaning can be a pivotal element in connecting the sound and shape of the Chinese characters.

According to Hoosain's (1991) analysis of the 3,500 Chinese characters, there are about 200 semantic radicals and 800 phonetic components. Some semantic and phonetic components can be stand-alone pictographs to depict objects or indicatives to symbolize ideas. Two or more semantic radicals can be combined to make a semantic compound character for a meaning concept. The stand-alone characters can also be transformed to be semantic radicals and phonetic radicals to make semantic-phonetic compound characters. Semantic radicals, referred to as sub-morphemic components, can provide clues to the general meaning for the semantic-phonetic compound characters. Making the connection between semantic radicals or the stand-alone characters and their meanings is a commonly used, effective character instructional activity for Chinese L1 learners (Wu et al., 2009; Wu, Li, & Anderson, 1999). The semantic radicals were also found to be useful as clues for retrieving the meanings and sounds of the instructed new words for Chinese L2 learners. (Shen, 2011; Shen & Ke, 2007).

Most of the Chinese words are two-character words. Morphological awareness—the ability to correctly add or subtract the morphemes in words and understand the

structural relationship between morphemes—is a core correlate in learning to read Chinese characters for Chinese L1 readers (McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003; Shu et al., 2006; Tong et al., 2017). Explicit instruction on morphemic knowledge and awareness improved the learning of Chinese word reading and vocabulary knowledge for Chinese L1 Children (Wu et al., 2009; Zhou et al., 2012).

Oral vocabulary knowledge, that is the connection between sound and meaning at the word level, has been found to be a strong correlate with Chinese word reading for native and non-native Chinese-speaking children (Zhou & McBride, 2015; Zhou et al., 2017). Studies on L2 adult learners showed that there was a significant correlation between recalling the sound and knowing the meaning of the word in Chinese L2 adult learners (Everson, 1998). Oral vocabulary knowledge was also found to provide full mediation for lexical morphological awareness at the character level and partial mediation for sublexical morphological awareness at the semantic radical level in Chinese word reading for Chinese L1 children (Tong et al., 2017).

In summary, the evidence suggests that meaning may not be independent from learning to read in Chinese, in part due to the nature of the opaque orthography and the meaning components at various levels.

4.1.2 Experimental Studies on the Role of Pinyin in Learning Chinese words

A series of experimental studies have explored the causal relationship between the use of Pinyin and the effectiveness of learning unfamiliar characters in Chinese L1 children. This relationship is mediated by the involvement of teacher's instruction and

students' literacy ability. In the studies where first grade native Chinese-speaking children were reading independently, incidental character learning was found more effective when the materials were captioned with Pinyin on all characters (Full Pinyin condition) or only on the focal new characters (Partial Pinyin condition) than when the materials were not captioned with Pinyin at all (No Pinyin condition) (Li, Wu, Zhang, Zheng, & Zhu, 2011; Wu et al., 2002).

However, the teacher's instruction can change the effect of Pinyin on the learning of Chinese characters. When the teacher provided robust instruction and specific activities to integrate the sound, meaning, and shape of the focal unfamiliar characters in whole group teaching, the learning of the characters' pronunciation was not significantly different between Full Pinyin, Partial Pinyin, or No Pinyin conditions (Wu, Li, & Liu, 2009). However, in shared-reading activities where the teacher did not provide specific instruction on the unfamiliar characters, the recall of unfamiliar characters' pronunciation was significantly less in the Partial Pinyin condition than in Full Pinyin or No Pinyin conditions (Wu, Li, Shu, Anderson, & Li, 2002). This indicates Pinyin is not more effective for students to connect the sound, meaning, and shape of the unfamiliar characters when teacher instruction on the unfamiliar characters is provided. Additionally, Pinyin captioning could interfere with the incidental learning of the unfamiliar characters when teacher did not provide robust instruction on the characters because learners may not engage all of their attention to integrate the shape, meaning, and sound of the unfamiliar characters, rather than being overloaded or distracted by the Pinyin captions.

A longitudinal study by Li, Wu, Zhang, Zheng, and Zhu (2011) compared students' learning of Chinese characters in a Full Pinyin condition and No Pinyin condition over a one-year instruction using the shared reading approach. The results again showed no significant difference between these two conditions. In addition, they found that students reported significantly lower self-efficacy when reading texts with Pinyin than those who read texts without Pinyin. The results suggest that students who were given texts with Pinyin were less motivated to read in Chinese than students who read texts without Pinyin. Taken together, Wu and his colleagues suggested that Pinyin captioning on unfamiliar characters interfered with the learning of Chinese characters. Full Pinyin learning condition may be a more effective method for low ability students in independent reading activities.

While Pinyin was not helpful for Chinese L1 children learning characters in instructional literacy activities, the role of Pinyin in the learning of characters for L2 learners of Chinese has not been clear. In a recent study, Wang, McBride, Zhou, Malatesha Joshi, and Farver (2018) compared the learning of unfamiliar characters between 29 native speaking children and 34 non-native speaking children in Hong Kong. Again, they found that native Chinese-speaking second or third graders who used phonological codes (an alphabetic system similar to Pinyin) were not significantly better at the learning of Chinese characters compared to students in the condition where students received look-say methods (Look-say condition), or who were given radical knowledge of the characters (Radical condition), or where students were given character copying training (Copying condition). However, non-native Chinese speaking students

learned new characters significantly better with phonological representations than those who were in the Look-say, Radical, or Copying conditions. The authors suggest that when phonological representations are provided, non-native Chinese speaking children with alphabetic language background as L1 could retrieve the pronunciation of Chinese characters better.

The effect of Pinyin captioning on learning the characters was mixed for adult learners. Chung (2003) compared the effectiveness of written Pinyin and verbal pronunciation as stimulus prompts on the learning of unfamiliar characters. Participants who were given written Pinyin feedback recalled significantly more characters than those who received verbal pronunciation feedback. However, the presence of Pinyin and Chinese characters simultaneously may not be a prime learning condition because Chinese L2 learners may focus more on Pinyin rather than on the shape of unfamiliar characters. Chung (2002) compared the learning of unfamiliar Chinese characters when written Pinyin prompts were presented at the same time or five seconds after displaying the characters with English-speaking adolescent or college learners of Chinese. He found that participants performed significantly better on the recall of unfamiliar characters' pronunciation when there was a temporal spacing to display the characters and Pinyin. These two studies suggested that adolescent participants benefited more from written Pinyin feedback than verbal demonstration in the learning of the unfamiliar characters, but the alphabetic Pinyin may hijack the students' cognitive resources when it is presented with the characters at the same time for L2 learners with an alphabetic orthography background.

Additionally, the mixed findings on the effect of Pinyin on the learning of Chinese characters may be due to the different ways in which students received the instructions when learning the unfamiliar characters. The series of studies conducted by Wu and his colleagues modelled the real classroom reading activities where students learned the new characters in meaningful contexts and in multiple literacy activities that tend to connect the sound, meaning, and shape of the Chinese characters. However, in the above-reviewed studies on L2 learners, the participants learned the new characters in decontextualized manners, relied on rote memorization skills, and only received one or the other training to learn the characters' pronunciation.

Unlike Chinese L1 learners who have developed strong oral vocabulary knowledge before learning to read, Chinese L2 learners acquire oral vocabulary knowledge at the same time as developing literacy skills. Because of the important role of meaning in Chinese reading acquisition, it is critical to examine the learning of both sound and meaning of Chinese words when the learners are provided with robust vocabulary instruction and engaged in meaningful reading activities that require them to make sense of texts.

4.1.3 Research Questions

The present study aimed to explore two key issues stemming from the previously reviewed existing literature: (1) whether the use of Pinyin captioning in reading materials can facilitate the MI students' learning of Chinese words (i.e., knowing the pronunciation and explaining the meaning) in whole-group teaching with meaningful reading activities;

and (2) the extent to which knowing the pronunciation is associated with being able to explain the meaning of the Chinese words among MI students.

4.2 Method

4.2.1 School Setting

Located in a Midwest state of the US, the school is an early total MI program implementing the intensive program model, with approximately 90% of instructional time in Mandarin from kindergarten for all subject matters. From the beginning of Grade 2, students are introduced to English literacy with seven English language arts class periods per week. The overall instructional time in Chinese decreases from 75% in Grade 3 to 50% in Grade 4. Chinese language arts, and social studies are taught in Mandarin, and English language arts, science, and math in English. Compared to other MI programs, the school sets relatively higher character recognition and production expectations. Students learn simplified Chinese characters from kindergarten. According to the self-report of the academic director, by Grade 5, students are expected to recognize about 2,000 characters and produce 1,500 characters. All classroom teachers are licensed and are native speakers of the languages in which they teach grade-level content (i.e., either in Mandarin or in English). At the administrative level, one English-speaking principal and one Mandarin-speaking academic director are responsible for executive and academic matters.

The school has excellent academic performance; the majority of the third graders could meet and exceed academic standards in reading and math in the state standardized

assessments assessed in English. The racial composition of the school is mainly White and Asian. Only a small percentage of students receive free or reduced-price lunch or special education services. Although a noticeable proportion of students have Asian backgrounds, the majority of students speak English as their first or dominant language.

4.2.2 Participants

The present study was part of a larger research project that recruited a total of 76 third graders (39 girls and 37 boys; mean age = 9.6 years) at the school. The majority of the participants had been enrolled in the MI program since kindergarten or Grade 1. Based on results reported in an earlier study conducted in the MI programs from the same state (Fortune & Song, 2016), most students' Chinese oral language proficiency levels were expected to range in Intermediate levels, using the rating scales and proficiency guidelines that are adapted for young learners and aligned with the American Council on the Teaching of Foreign Languages (ACTFL). At this school, the Pinyin system is introduced in Chinese language arts at the beginning of Grade 3. At the intervention of the study, the students had learned all the Pinyin symbols for almost an academic year.

4.2.3 Materials

The learning materials included four stories, two of which were adapted from (Wu et al., 2002). The other two stories were found online within a similar genre and tailored to a comparable length as the first two stories, approximately 100 characters total. Each story was organized in six pages with one illustration on each page. Based on

consultation with classroom teachers, each story included five two-character Chinese words that were new to the students, and the rest of the characters in the stories were familiar to them. Each story was created with three formats of booklets: (a) all characters were captioned with Pinyin (Full Pinyin condition); (b) only five focal new words were captioned with Pinyin (Partial Pinyin condition); and (c) no Pinyin caption was present at all (No Pinyin condition) (see the first pages in Pinyin and No Pinyin conditions of Story 4 in Appendix E). The author of the study was the instructor to teach all stories to all classes. In order to assure that the teaching procedures and materials would work with targeted student population, the researcher piloted teaching one of the four stories in advance at another school where students' academic achievements were commensurate with the students at this participating school. This piloting part of the process showed that the protocol would likely unfold as planned among the participants of the current study.

4.2.4 Intervention Procedures

The lesson plans were developed to teach the four stories using a whole-group teaching method. Reading activities were organized in five steps, routinely used by the instructor: (a) introduction, (b) vocabulary instruction, (c) teacher reading modelling and comprehension checking, (d) student choral reading, and (e) wrapping up by reflecting the moral of the story. These activities involved teacher-initiated, teacher-modelling, and whole-group activities. Each class lasted approximately 50 minutes. The instructor first taught the five focal words on the white board with PowerPoint slides. During vocabulary instruction, the teacher organized particular activities to integrate the sound, meaning,

and shape of the new focal words. Specifically, in Partial and Full Pinyin conditions, the teacher first led the students in a reading of Pinyin symbols corresponding to each focal word. For example, the teacher modelled a reading of the two-character word 孤独 (lonely) using its Pinyin /gu1 du2/ on top of each character projected on the white board. The teacher first segmented each character's Pinyin into two parts (i.e., initial and final), and then integrated parts into a whole syllable, such as pronouncing /g/ and /u1/ separately first, and then blending them together /gu1/. The tone was pronounced on the final. The same process was used for the second character by pronouncing /d/, and /u2/ separately, and then blending the parts into a whole tonal syllable /du2/. The teacher and the students repeated the segmenting and blending process for a second time. The students were asked to read the Pinyin of the two characters on their own for a third time. Within the No Pinyin condition, the teacher only orally demonstrated the holistic pronunciation of the words without using Pinyin notation or segmenting the syllable of the characters. The teacher demonstrated the pronunciation of /gu1 du2/ once and then the students were asked to follow the teachers' demonstration and repeat the pronunciation on their own for a third time.

After imitating the pronunciation of the word, the teacher pointed out the visual representation on the white board next for the word and explained the meaning of the word. The teacher used both definitional and contextual explanations with three student-friendly examples and/or gestures to help students understand the meaning of the word. For the compound word with transparent morphemes, the teacher related each morpheme to a familiar concept. For example, in the word 孤独/gu1du2 (lonely), the teacher pointed

out that each character means *being lone* by itself and the character 孤/gu1 in a familiar concept of 孤儿/gu1er2 (*orphan*) and the character 独/du2 in 单独/dan1du2 (*alone*), both meaning *being alone*. Then, students were engaged to understand the word with some questions, such as 你会孤独吗 [Do you ever feel lonely] ? Next, the teacher directed students' attention to the shape of the characters. Students were asked to name the structure of each character in the two-character word. For compound characters, students were asked to name the semantic and phonetic radicals. For integral characters or the character components students could not name, they were asked to name the sub-components or write the character components stroke by stroke in the air using their finger, which is a common character learning activity in their class.

After going through the activities focusing on sound, meaning, and shape of the words, students had to complete a worksheet on the five focal unfamiliar words to enhance their learning of the new words. In Pinyin conditions, the teacher gave the students two exercises: first was a matching exercise that asked the students to pair the five focal unfamiliar words and their Pinyin symbols; second was a sentence cloze test that required the students to fill the five focal words in the five sentences. In the No Pinyin condition, students only completed the sentence cloze exercise and the focal words were not captioned with Pinyin (see Appendix F).

The next reading activities included the teacher modelling reading, student comprehension checking, teacher-students reading together sentence by sentence, and students independently read aloud. During the first read aloud, the teacher pointed to each character with his finger as he demonstrated reading. To help students comprehend the

texts, the teacher read the sentences and asked two related questions in each page. The questions required students to restate, connect to previous sentences, infer, predict, or summarize the information in the texts. Next, the teacher read one sentence and students imitated reading the sentence. Last, students were asked to read the story sentence by sentence chorally. When students encountered challenges, the teacher provided scaffolding at the point of difficulties. Lastly, after completing all reading activities, the teacher wrapped up the lesson by asking students about what the story had told them.

4.2.5 Study Design and Data Collection

To examine the causal relationship between the use of Pinyin and the learning of Chinese words, a crossover design was used to compare the effectiveness of learning in the Pinyin conditions and No Pinyin condition. The students were crossed over the Full Pinyin, Partial Pinyin, No Pinyin, and No Instruction conditions. In the No Instruction condition, students did not learn the story. Their performance in the No Instruction condition was used as baseline scores to assess their familiarity with focal words in terms of sound and meaning. To assign each of the four classes randomly to one of four conditions, the study followed Wu et al. (2002) using a 4 by 4 Latin Square design (see Table 4.1) to control for the effect of text difference. The first two stories (S1 and S2) were taught on the Wednesday of the given week and tested on the next Tuesday; the other two stories (S3 and S4) were taught on the Thursday of the given week and tested on the following Wednesday. This is due to the severe winter weather during the study where one Wednesday school day was cancelled. The teaching of the stories in the Pinyin

conditions and No Pinyin condition were also balanced out in the mornings and in the afternoons.

Table 4.1 *Latin Square Design Assigning the Four Classes in the Four Conditions*

	F	P	N	NI
W1: S1	A	B	C	D
W2: S2	D	A	B	C
W3: S3	C	D	A	B
W4: S4	B	C	D	A

Note. F = Full Pinyin condition, P = Partial Pinyin condition, N = No Pinyin condition, NI = No Instruction condition.
Class A, B, C, D are represented as A, B, C, and D, respectively.
Week 1 to 4 are represented as W1, W2, W3, and W4, respectively.
Story 1 to 4 are represented as S1, S2, S3, and S4, respectively.

4.2.6 Measures and Instruments

Word Naming and Word Meaning Explanation

To examine the students' learning of the five focal new words taught in each story, two tasks—word naming and word meaning explanation—were given to all students six days after experiencing each condition. In the task of word naming, pronouncing both two characters in a word correctly earned one point. In scoring students' word naming, students were not penalized for not using the correct tones because they often used rising intonation when not certain about the pronunciation of the characters. Therefore, it was challenging to decide whether they had known the tones of the characters. Accurately explaining each word received one point. Their responses were determined by their understanding of the words' meaning. The students were encouraged

to explain a word by using the word in a sentence, translating the word into English, or using gestures to point to an object. Their oral responses were recorded on answer sheets by the trained experimenters.

According to Beck, McKeoun, and Kucan's (2002) definition of word tier, these 20 focal new words were categorized into Tier 1 words (n = 8) and Tier 2 words (n = 12). Tier 1 are more basic and concrete in meaning, such as 玻璃/bo1li2 (*glass*), 铁锤/tie3chui2 (*metal hammer*), or 轮胎/lun2tai1 (*tire*); Tier 2 words represent more precise or mature ways of referring to more complex or abstract ideas and meaning concepts 独孤/gu1du2 (*lonely*), 骄傲/jiao1ao4 (*proud*), or 捣乱/dao3luan4 (*to make a mess*).

Chinese Word Reading

To tap into students' general Chinese literacy knowledge previously acquired in their program, the measure of Chinese word reading was tested at the end of the study. The Chinese word reading task included 20 single-character and 60 two-character words. These words were chosen from children's Chinese textbooks and storybooks. Children were asked to name each word presented on a paper. Scores were based on the number of correctly named characters. The total possible score for this task was 80. The task was administered individually with trained experimenters. If a child failed to name 10 item words consecutively, the testing was stopped. The internal reliability (Cronbach's α) of the task in the present study is .92.

4.2.7 Data Analysis

Descriptive analysis, contrast analysis, and two-level multilevel analysis were used to compare the learning of Chinese words in the four conditions. Descriptive analysis provided raw scores for correctly naming or explaining each word in each condition. Three sets of contrasts were set up to compare the learning of sounds and meanings of the Chinese words between conditions: Full Pinyin and Partial Pinyin conditions, No Pinyin and Pinyin conditions (i.e., Full and Partial Pinyin combined), and No Instruction and the three learning conditions combined (see Table 4.2). Finally, multilevel modelling was used to compare the learning in the Pinyin and No Pinyin conditions by taking account of students' prior Chinese literacy knowledge and word tier. Multilevel modelling is more appropriate than single-level regression analysis or fixed-effects ANOVA in the present study because this approach takes into account of the fact that there are multiple observations from each participant, which violates the assumption of independence of the observations in single level models. Multilevel regression analysis provides information on fixed and random effects of the between-students variable at Level 2. Because the scores in the tasks of Word Naming and Word Meaning Explanation were either 0 or 1, multilevel logistic regression models were created. The significance threshold of all the analyses was set at .05.

Table 4.2 *Comparisons Weights for Each Conditions in Contrast Analysis*

	P vs. F	N vs. P + F	NI vs. N + P + F
NI	0	0	1
N	0	1	-1/3
P	1	-1/2	-1/3
F	-1	-1/2	-1/3

Note. NI = No instruction, N = No Pinyin condition, P = Partial Pinyin condition, and F = Full Pinyin condition.

In the multilevel models, the response variables are the correct scores for each word in the tasks of Word Naming and Word Meaning Explanation. The three levels of learning conditions are within-students variable at Level 1, the categorical variable of word tier (WT) is a within-students variable at Level 1, and the continuous variable of Chinese word reading (CWR) is a between-students variable at Level 2. The fixed effects were modelled at level 1 for learning conditions and WT. The random effect was modelled at Level 2 for CWR. The formula is expressed as follows:

$Y_{ij} = \beta_{0j} + \beta_{1j}\text{condition}_{ij} + \beta_{2j}WT_{ij} + r_{ij}$ (Level 1 model)

$\beta_{0j} = \gamma_{00} + \gamma_{01}\,CWR_j + u_{0j}$ (Level 2 model)

$\beta_{1j} = \gamma_{10}$

$\beta_{2j} = \gamma_{20}$

$Y_{ij} = \gamma_{00} + \gamma_{01}\,CWR_j + u_{0j} + \gamma_{10}\text{condition}_{ij} + \gamma_{20}WT_{ij} + r_{ij}$ (Multilevel model)

Y_{ij} is the observed score in word *i* for student *j*.

γ_{00} is the mean score in the No Pinyin condition.

γ_{01} is the coefficient for the Level 2 factor of Chinese word reading.

u_{0j} is the residual for student *j* at level 2.

γ_{10} is the coefficient for the Level 1 predictor of condition.

γ_{20} is the coefficient for the Level 1 predictor of word tier.

r_{ij} is the residual in word *i* for student *j*.

Therefore, the multilevel logistic regression model for the task of Word Naming (WN) and for the task of Word Meaning Explanation (WME) as the response variable are expressed as follows:

$$\text{Logit}(WN_{ij}) = \gamma_{00} + \gamma_{01}\,CWR_j + u_{0j} + \gamma_{10}\text{condition}_{ij} + + \gamma_{20}WT_{ij} + r_{ij} \text{ (Multilevel model)}$$

$$\text{Logit}(WME_{ij}) = \gamma_{00} + \gamma_{01}\,CWR_j + u_{0j} + \gamma_{10}\text{condition}_{ij} + \gamma_{20}WT_{ij} + r_{ij} \text{ (Multilevel model)}$$

4.3 Results

RQ1. Does the use of Pinyin captioning in reading materials can facilitate the learning of Chinese words in meaningful reading activities?

4.3.1 Descriptive Analyses

Descriptive statistics for the correctness of word naming and word meaning explanation in four conditions are displayed in Tables 4.3 and 4.4. The mean scores of Word Naming and Word Meaning Explanation were very low in the *No Instruction* condition, indicating that the focal characters were mostly unfamiliar to the students or the students were not able to guess the sound or meaning of the characters. In both tasks, the mean scores in the No Pinyin condition were noticeably higher than those in *Partial Pinyin* and *Full Pinyin* conditions. The mean scores between *Full* and *Partial Pinyin* conditions were very similar.

Table 4. 3 *Descriptive Results in the Task of Word Naming*

Condition	*M*	*SD*	*Min*	*Max*
Full Pinyin (*n* = 71)	1.06	1.11	0	5
Partial Pinyin (n = 69)	1.06	1.36	0	5
No Pinyin (n = 70)	1.27	1.51	0	5
No Instruction (n = 76)	0.09	0.37	0	2

Note. The possible total score in each task in each story was 5.

Table 4. 4 *Descriptive Results in the Task of Word Meaning Explanation*

Condition	*M*	*SD*	*Min.*	*Max.*
Full Pinyin (*n* = 71)	1.23	1.24	0	5
Partial Pinyin (n = 69)	1.35	1.50	0	5
No Pinyin (n = 70)	1.51	1.60	0	5
No Instruction (n = 76)	0.09	0.41	0	3

Note. The possible total score in each task in each story was 5.

4.3.2 Contrast Analyses

The contrast analysis results showed that only the contrast between the No Instruction condition and the mean of the other three learning conditions combined was statistically significant for both tasks (WN: $p < .001$; WME: $p < .001$). On average, students in all three learning conditions could name .78 more words or explain .95 more words than No Instruction condition. The results suggested that students performed significantly lower in No Instruction condition than in the three learning conditions, indicating that teaching was effective in all three learning conditions. However, students in the Full Pinyin did not name more words, and only explain 0.06 more words than students in the Partial Pinyin condition, and no significant differences were found in both tasks (WN: $p = .99$; WME: $p = .57$, respectively). In the No Pinyin condition, students, on average, were able to name 0.14 more words or explain 0.15 more words than students in the Full Pinyin and Partial Pinyin conditions combined, but the differences were not significant in both tasks (WN: $p = .21$; WME: $p = .22$, respectively). The results suggest that the differences in the Chinese word learning between the three learning conditions were not beyond chance level.

4.3.3 Multilevel Model Analyses

Next, Multilevel model analyses were used to estimate the effects of learning condition and another two variables (students' prior Chinese literacy knowledge and word tier) on the learning of each word. First, to estimate intraclass correlation (ICC), unconditional two-level models (conditions-within-students) were fitted to the scores of the two tasks: Word Naming and Word Meaning Explanation. The ICCs for the unconditional models were .21 and .28, respectively, indicating that 21% of the variance in recalling the sounds and 28% of the variance for knowing the meanings of the Chinese words was accounted for by variance between students. Therefore, multilevel models should be adopted because there is variation to be explained by the random effect of students (Raudenbush & Bryk, 2002).

The next set of models included the Level 2 between-students variable of students' prior Chinese literacy knowledge and the other was a categorical variable indicating the tier each word was assigned to as a Level 1 variable. Since the research question compares the learning of Chinese words in the Pinyin and No Pinyin conditions, the No Instruction condition was excluded in the models. First, the full models including interaction terms between the three learning conditions, Chinese word reading, and Tier were fitted. Further chi-square analysis showed that the reduced model without interaction terms were not statistically different from full models for the task of Word Naming ($\chi^2 = 7.76$, $df = 7$, $p = .35$), or for the Word Meaning Explanation task ($\chi^2 = 6.28$, $df = 7$, $p = 0.51$). Therefore, the reduced models for these two tasks were adopted.

The reduced models for the fixed and random effects for Word Naming and Word Meaning Explanation were reported in Table 4.5 and Table 4.6, respectively. The reference groups were the No Pinyin condition and Tier 2 words. The reduced models indicated that there was a statistically significant main effect of students' prior Chinese literacy knowledge and word tier on both Word Naming and Word Meaning Explanation scores, but no significant effect on the learning conditions. For the Word Naming task, on average, a one-point increase in Chinese word reading was associated with a 9% increase in the odds of naming the words correctly. The minimum, medium, and maximum scores in Chinese word reading were 9, 53, and 73. The highest scoring student was 576% or 189% more likely to learn the pronunciation of the new words than the lowest scoring students or the median scoring student, respectively. For the Word Meaning Explanation task, a one-point increase in Chinese word reading on average was associated with an 8% increase in the odds of being explained the words correctly. Similarly, the highest scoring student in Chinese word reading was 512% or 160% more likely to learn the meaning of the new words than the lowest scoring students or the median scoring student, respectively.

The significant effect on word tier suggested that the odds for Tier 1 words being recognized correctly, on average, was 418% more than Tier 2 words in odds of being recognized correctly. For Word Meaning Explanation task, on average, Tier 1 words was were 507% more likely to be explained correctly than Tier 2 words.

Table 4.5 *Multilevel Logistic Regression Results for Predicting Each Word to be Named Correctly in the Task of Word Naming*

Fixed Effect	*Odds Ratio*	*B*	*SE*	*z*	*p*
(Intercept)	.00	-6.39	.53	-12.10	< .001
Full Pinyin (*n* = 71)	.78	-.25	.20	-1.24	.21
Partial Pinyin (*n* = 69)	.76	-.27	.20	-1.33	.18
CWR	1.09	.08	.01	9.68	< .001
Tier	4.18	1.43	.18	8.07	< .001
Random Effect	Variance	*SD*			
Student	.04	.20			

Note. The reference groups are No Pinyin condition (*n* = 70) and Tier 2 word. The possible scores for naming each word are 0 or 1.

Table 4.6 *Multilevel Logistic Regression Results for Predicting Each Word to be Explained Correctly in the Task of Word Meaning Explanation*

Fixed Effect	*Odds Ratio*	*B*	*SE*	*z*	*p*
(Intercept)	.00	-6.23	.68	-9.18	< .001
Full Pinyin (*n* = 71)	.72	-.35	.20	-1.74	.08
Partial Pinyin (*n* = 69)	.82	-.20	.20	-1.01	.31
CWR	1.08	.08	.01	7.00	< .001
Tier	5.07	1.62	.18	9.18	< .001
Random Effect	Variance	*SD*			
Student	.63	.79			

Note. The reference groups are No Pinyin condition (*n* = 70) and Tier 2 word. The possible scores for explaining each word are 0 or 1.

RQ2. What is the relationship between naming characters and explaining word meaning?

4.3.4 Correlation between Recalling the Sound and Knowing the Meaning

Because each word has two characters, the correctness of each character in the two-character words was calculated. The matrix in Table 4.7 shows the occurrences of correctly named characters and explained words in the tasks of Word Naming and Word Meaning Explanation for all the participants who received the instruction on the 15 two-character words in the three learning conditions. Results from a chi-square test for Cramer's *V* showed that there was a statistically significant correlation between the correctness in naming characters and explaining word meaning ($\phi = 0.77$, $\chi^2 = 852.36$, $df = 2$, $p < .001$).

Table 4.7 *Counts of Correctness for Character Naming and Word Meaning Explanation for 15 Words in Three Stories by Row (%)*

	No Character Correct	One Character Correct	Two Characters Correct	Total
Word Meaning Explanation Incorrect	1008 (88.5)	102 (9.0)	29 (2.5)	1,139 (100)
Word Meaning Explanation Correct	47 (16.2)	30 (10.3)	214 (73.5)	291 (100)
Total	1,055	132	243	2,280

4.4 Discussion

The present study sought to explore the causal relationship between the use of Pinyin in reading materials and the learning of Chinese words in meaningful reading activities with elementary MI students. The results in the present study revealed that MI students learned the Chinese words better without Pinyin than with Pinyin when the teacher orally demonstrated the pronunciation of the unfamiliar words during robust vocabulary instruction and meaningful reading activities, but the difference was not statistically significant. These findings suggest that the Pinyin representation was not superior to the instructor's oral demonstration for MI students in learning the new Chinese words. These results are consistent with studies on Chinese L1 children (Li et al., 2011; Wu et al., 2009; Wu, Li, et al., 2002). In addition, students actually did one extra activity to match the words and their Pinyin symbols in the Pinyin conditions. Although there is no statistically significant difference in the scores of the two tasks between the No Pinyin condition and the Pinyin conditions, this difference of learning thousands of characters with or without Pinyin could exponentiate over years. It is an important future research agenda to test the longitudinal effect of the use of Pinyin on the learning of Chinese words.

There are some possibilities to explain MI students' lower performance in the Pinyin conditions than the No Pinyin condition to learn Chinese words. The first explanation is that when the reading materials had no Pinyin captions, students had to retrieve the sounds of the unfamiliar words in reading activities. The instructor found students had more struggles, asked more questions, and needed more support when doing

the exercises and read aloud on their own. The No Pinyin condition created opportunities for them to wrestle with the unfamiliar words.

The second possible reason might be that exposing students to Pinyin symbols on the top of the words in the texts or in reading activities, together with auditory pronunciation from the instructor, may increase the cognitive load (Lee & Kalyuga, 2011). Unlike Chinese L2 college students, English speaking young children were not proficient in spelling Pinyin after learning Pinyin orthography for almost an entire academic year (see Study 3 in this dissertation). Compared to Chinese L1 children, MI learners had developed Pinyin spelling at a much slower rate, likely due to the fact that these English-Chinese bilingual learners were still in the process of developing sensitivity to Chinese phonology and were also influenced by their English orthographic knowledge. Pinyin may not be an effective tool for them in the learning of Chinese characters yet.

Two additional predictors of Chinese word reading were identified that had significant relationships with the learning of the Chinese words. The first is the MI students' prior Chinese literacy knowledge, which is consistent with the previous studies (Wu et al., 2009). The finding suggests that the learning of new Chinese words was significantly related to their prior Chinese knowledge. In other words, those students who have better Chinese literacy knowledge learned more new words than those who had lower Chinese character knowledge. Additionally, students' prior Chinese literacy knowledge did not have a significant interaction effect with the learning conditions, indicating that the difference in learning the new words for students who have different levels of Chinese literacy knowledge remained similar across the learning conditions.

Students' prior Chinese literacy knowledge has a large impact on the learning of the new words. If they did not have a good foundation of Chinese literacy knowledge, they would be less likely to acquire new words later.

The next identified variable was the types of words in the stories, which had large effect sizes in the learning of the new Chinese words. This finding is important, because Tier 2 words were more challenging to acquire in oral vocabulary for MI learners (Fortune & Ju, 2017), and Tier 2 words were also more difficult to learn in reading for L2 learners of Chinese. This relationship between oral vocabulary acquisition and reading development may have a reciprocal relationship in language learners (Stanovich, 2004). Compared to Chinese L1 children, young L2 learners of Chinese lack oral vocabulary knowledge, which could impede their learning of new written words in the classroom, and insufficient reading knowledge in turn could hinder their learning of vocabulary knowledge.

During intervention, the students only received one 50-minute instruction on the five new words in each story. The instruction would not guarantee that all students had acquired the new words, although the students were given worksheets to use the new words in new contexts and each student was given corrective feedback on their answers. In reality, classroom teachers would review newly introduced words in multiple class periods and the learning outcomes would presumably better. Given that, the learning of Tier 2 words can be more challenging than that of Tier 1 words. The difference in the learning of Tier 1 and Tier 2 words could in part indicate MI students' difficulty of

advancing to higher language proficiency levels due to low oral vocabulary knowledge (Fortune & Ju, 2017).

MI students' language proficiency has been found to be consistently lower than their peers in alphabetic immersion programs (Burkhauser et al., 2016; Fortune & Song, 2016; Watzinger-Tharp et al., 2018). The difference in the skill area of reading was even wider (Burkhauser et al., 2016; Watzinger-Tharp et al., 2018). One important factor to explain the high reading performance for alphabetic immersion students is that English and other alphabetic languages (e.g., Spanish, French) share many cognates in which the meaning of the words can transfer. Due to the morphological formation differences in Indo-European and Chinese language, however, English L1 children have to acquire these words in Chinese by accumulating oral vocabulary knowledge and deeply understand the morphology of Chinese. Because of the relatively small effect size of learning conditions in the present study, word tier had a relatively much larger effect size. That is to say, whether or not captioning Pinyin may not be important in learning Chinese characters but providing more scaffolding to help students understand and internalize Tier 2 words can make a much larger impact on their learning of new Chinese words.

The present study also evidenced a high correlation between knowing the pronunciation and being able to explain the meaning of Chinese words. The majority of Chinese words are two-character words, and each character corresponds to a syllable and may or may not contribute to the meaning of the word. Knowing only one character is not enough to recognize the other character or explain the meaning of the whole word. Readers have to map each character to its sound and meaning. Because Chinese

characters do not have phonemic level sound-symbol correspondence, learners may have to rely on meaning to form a bond between phonology and orthography (Ouellette, 2006). The present study provides important evidence to suggest the pivotal function of meaning in mapping sound to symbol in learning to read Chinese. It extends the current theoretical accounts on phonology-based and orthography-based learning (Ho, Yau, & Au, 2003; Rayner et al., 2001), which may not be able fully capture Chinese reading acquisition. The research design of learning the characters in meaningful contexts is not only more ecologically valid, but also more theoretically appropriate because of the pivotal function of meaning in Chinese reading acquisition.

4.5 Conclusions and Implications

The present study suggests that the use of Pinyin does not facilitate the learning of Chinese words in meaningful reading activities with teacher scaffolding for third graders in the total early MI program. Although the difference was not statistically significant, students learned Chinese words better without Pinyin notations. The findings are important for program administrators, teachers, and parents to make decisions on when to teach Pinyin and how to use Pinyin in their MI programs. However, there is no doubt that Pinyin is an important component of Chinese curriculum for MI students, because Pinyin is more of a tool for students to learn Chinese characters on their own and type characters on digital devices. In some programs, MI students at higher academic grades have literacy block time to read and write independently, and they need Pinyin as an additional resource to read and substitute unfamiliar Chinese characters. In addition, students use

the Pinyin input method to type characters on Google Docs to fulfil the state requirements of computer literacy. Therefore, this topic is more complex than whether Pinyin facilitates or hinders the learning of Chinese.

The study also found that knowing the pronunciation and being able to explain Chinese words are significantly associated. Providing strong oral vocabulary knowledge (i.e., making sound and meaning association) and instruction on character knowledge (i.e., making meaning and shape associations) are crucial in the Chinese character literacy instruction. The challenge may be that the characters in the words are not transparent or reliable to associate with the concepts of the words (e.g., Dunlap, Perfetti, Liu, & Wu, 2011). Teachers have to make decisions on when and how to introduce these meaning components to facilitate understanding, rather than confusing students. Another challenge is the teaching of more abstract, nuanced Tier 2 words. This might be true for all L2 learners. As Beck, McKeown, and Kucan (2002) acknowledge, robust vocabulary instruction plays a critical role to enlarge L2 learners' repertoire in classrooms rather than relying on incidental learning from contexts on their own, especially the instruction on Tier 2 words that require multiple practices and reviews. For this reason, providing morphemic knowledge has the potential to improve Chinese reading for MI students, as suggested for Chinese L1 children (e.g., Ku & Anderson, 2003; Wu et al., 2009).

Additionally, in terms of the curriculum design in MI programs, it is important to consider how to maximize MI students' oral vocabulary knowledge and character learning opportunities, especially in the early grades when MI students develop their language proficiency more quickly than mid or late elementary grades (Fortune & Ju,

2017). Because of the lower potential and challenges in transferring the linguistic and orthographic knowledge from their L1 English to learning L2 Chinese, MI students would need more instructional time to develop character and oral language knowledge than students in alphabetic immersion programs. Therefore, early total MI programs have more potential than early partial programs to help students become bilingual and biliterate when they exit their immersion programs. This assumption needs more comparative studies on early total and early partial MI program models, but it is believed that "the more time spent learning in the language, the higher language proficiency immersion children can attain" (Fortune, 2019, paragraph 8).

Whether increased Pinyin spelling proficiency or the heightened Chinese phonological awareness promotes Chinese word reading is a question that cannot be answered by the present study, and which remains on the research agenda for the field. Further studies are needed to test the generalizability of the findings on the use of Pinyin and Chinese word learning in early partial MI or other types of bilingual programs with young L2 learners of Chinese.

Chapter 5

Learning Chinese Sounds and Pinyin Spelling in Elementary Mandarin Immersion Students

5.1 Introduction

Mandarin immersion (MI), as a newcomer to the dual language and immersion education, now has more than 300 programs (Mandarin Immersion Parents Council, 2019). Thousands of young second language (L2) learners of Chinese learn subject-matter content through the medium of Mandarin Chinese. As a critical component of literacy curriculum, Pinyin is introduced to MI students either at Grade 1, Grade 2, or Grade 3, together with the other two orthographies: Chinese characters and English. The curricular design on when to teach Pinyin and how to use Pinyin is a controversial topic. More and more scholarship on this topic is emerging to suggest that Pinyin can be an important tool to promote spoken Chinese and accelerate Chinese character learning for L2 young learners (Curtain et al., n.d.; Lü, 2017; Wang et al., 2018). However, the majority of current MI programs do not introduce Pinyin until Grade 2 or Grade 3 (Everson, Chang, & Ross, 2016). MI parents and MI program administrators express concerns about their current curriculum of relatively late Pinyin introduction and the ongoing quandary of whether or not to introduce Pinyin earlier.

Using Pinyin to learn Chinese characters has to depend on high proficiency level of Pinyin literacy, especially when MI students are engaged in independent learning activities, such as using Pinyin to learn Chinese characters, to look up unfamiliar

characters in a dictionary, or to type on digital devices using Pinyin input method. Pinyin literacy development is fairly quick for children who speak Chinese as their first language (L1) (Cheung & Ng, 2003). However, Pinyin literacy development for Chinese L2 children is still unknown in the current literature.

Pinyin literacy development may depend on L2 learners' Chinese phonology acquisition. Researchers and educators often discount that MI students have to acquire the phonological system of Chinese, which can take place at the same time and as a result of oral vocabulary knowledge development (e.g., Goswami, 2001; Metsala, 1999). To date, there have been much fewer studies on the form than the function of interlanguage in the field of second language acquisition (SLA) research (Tarone, 2005). Some interlanguage phonology research that has been done on L2 learners in alphabetic immersion programs found that immersion students do not achieve nativelike pronunciation (Harada, 1999; Menke, 2010; Snow & Campbell, 1985), but no studies exist to investigate MI students' phonological competences, especially prior to Pinyin instruction. Because Pinyin spelling primarily depends on the acquisition of Chinese phonological knowledge and sensitivity and the learning of Pinyin symbol knowledge, consequently, it is unknown to what extent the interlanguage phonology influences MI students' Pinyin spelling.

Additionally, MI students are English proficient and often receive English literacy instruction before they are introduced to the Pinyin system—at school or in their homes or communities. It is also unclear about the cross-language influence of English literacy knowledge on the Pinyin spelling development for MI students. The present study aimed

to explore the characteristics of third-grade MI students' interlanguage phonology of Chinese before Pinyin introduction and their Pinyin spelling development after learning the Pinyin system for almost an academic year.

5.1.1 Learning the Phonology of Standard Chinese

English monolingual children stabilize in their English phonological system around age 5 or even later in early elementary grades (see a detailed review in McLeod & Crowe, 2018). When these English proficient children enroll in MI programs, they need to acquire the phonological system of Mandarin Chinese. Mandarin Chinese is also referred to as Standard Chinese (henceforth SC), *Putonghua*, or the "common speech" that is predominantly spoken in mainland China or Taiwan. Based on Selkirk's (1982) Sonority Sequencing Principle, SC syllable (σ) structure is divided into onset and rime at the most sonorous element (usually the vowel), $(C_{0\text{-}1})G(_{0\text{-}1})VC(_{0\text{-}1})$ (C = consonant, G = Glide, V = Vowel; see Figure 2). Of all 22 SC consonants (see Appendix G), ten of which—[tʂ], [tʂʰ], [ʂ], [ts], [tsʰ], [ɕ], [tɕ], [tɕʰ], [x] and [ɻ][1]—differ greatly from the American English (AE) sounds (Lin & Johnson, 2010). Only two syllable-final consonants, [n] and [ŋ], follow the Chinese vowels. In SC, there are three glides, including the high front [j] and high back [w] that are shared with AE, and the Chinese-specific high front rounded glide [ɥ]. Within ten monophthongs (see Appendix H), the high front rounded [y] and the mid back unrounded [ɤ] do not have equivalents in AE (see Figure I.1 & 2 and Figure I.3 & 4). The low front monophthong [a] only occurs as

[1] This paper adopts broad transcription, but in some cases, narrow transcription is used to differentiate allophones.

part of AE diphthong [ai]. In addition, the apical vowel [ɹ̩] only appear after dental consonants [ts], [tsʰ], and [s], and [ɻ̩] only after post-alveolar consonants [tʂ], [tʂʰ], [ʂ], and [ʐ̩] (Duanmu, 2000; Lee-Kim, 2014; Lin, 2007). The four SC diphthongs include [ei], [ai] and [ou] that have AE equivalents, and the [ɑu] that is Chinese-specific (see Appendix I). As a tonal language, SC has four tones contrastive in pitch contour: high-high, mid-high, low-high, and high-low, but the third tone, low-high, is often pronounced as low-low (Lin, 2007). Some syllables do not bear a tone in lexical words, usually referred to as weak tone. The tones will be transcribed by 1, 2, 3, 4, or 0 after each syllable in this study.

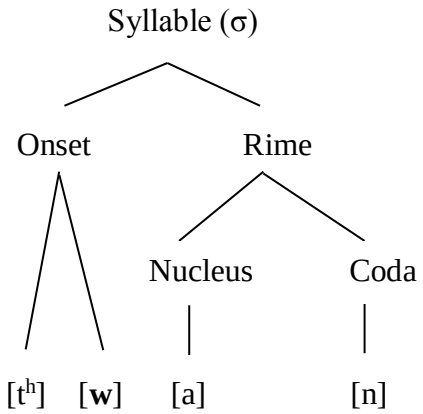

Figure 2. The possible SC syllable structure with a glide (Lin, 2007)

Presumably, these bilingual MI children can transfer shared phonemes from their L1 English to L2 Chinese, but they have to acquire Chinese-specific linguistic units. To date, only one study used the linguistic contrastive analysis approach by comparing SC and AE consonants to explain the challenging SC consonants for Chinese L2 adult learners who are monolingual English speakers (Lin, 2005). Bassetti (2006) investigated

how Pinyin input, some of which do not have one-on-one mapping for the vowels, affects Chinese L2 adult learners' phonological representations and, consequently, leads to incorrect pronunciation by omitting vowels. However, no studies have examined the phonological acquisition in Chinese L2 children prior to Pinyin instruction.

5.1.2 Learning the Pinyin System

The phonological system of SC corresponds to two orthographies, the primary orthography of the Chinese characters that people use to read and write and the alphabetic Pinyin system as the phonological transcription that is used to learn Chinese characters or to type in digital devices. Pinyin orthography appears usually on top of the unfamiliar Chinese characters in reading materials to denote sounds. In MI elementary programs, these English L1 children are first introduced to the Chinese characters, and the introduction of English literacy or the Pinyin system may vary.

MI students usually have acquired some basic English literacy from their caretakers or surrounding environments even before enrolling into their programs. English literacy may begin at kindergarten in early partial MI programs, or at second or third grade in early total programs. Based on *Orthographic Depth Hypothesis* (Katz & Feldman, 1983; Katz & Frost, 1992; Seymour et al., 2003), English is considered a deep orthography with many irregular spellings and sound varieties in words (Ehri, 1998). To become proficient readers and spellers, children have to acquire the grapheme to phoneme correspondence (GPC) rules by mapping about 70 English letters and letter combinations onto 40 phonemes (Ehri, 1998).

The Pinyin system is an alphabetic orthography with 26 Roman letters and four tones. The difference between Pinyin system and English letters is the addition of the letter *ü* for the high front rounded vowel [y], and the omission of the letter *v*. Instead of using the phonemic inventory of consonants and vowels, the Pinyin system has 21 syllable initials and 35 syllable finals, together with the four diacritic marks to represent tones on the finals (Committee of Chinese Writing System Reform; see Appendix J). Different from the syllable structure division described above, the letters for the three glides are grouped in Pinyin finals. Most Pinyin initials and finals are reliable, but the letters, *a, e, i, o, u,* corresponding to the glides/vowels do not have a one-on-one mapping relationship in different contexts of the Pinyin finals.

Chinese L1 children's Pinyin spelling development can be influenced by their L1 Chinese phonology, Pinyin orthographic knowledge, and the sound-letter correspondence rules in Pinyin. The Pinyin system is usually introduced to first graders in eight weeks and then they can use the Pinyin symbols to read texts with unfamiliar Chinese characters. However, learning to spell in L2 can be more challenging than L1 spelling development, in part because L2 spelling can be influenced by the phonology, orthography, and the mapping rules in both L1 and L2 (James & Klein, 1994; Helman & Bear, 2007).

As previous research findings suggested, the two main factors that could facilitate or interfere with the spelling proficiency in L2 are: (1) the consistency of pronunciation between L1 and L2, and (2) the same or different GPC correspondence rules between L1 and L2 (Fashola, Drum, Mayer, & Kang, 1996; Helman & Bear, 2007; James, Scholfield,

Garrett, & Griffiths, 1993; Luelsdorff, 1986; Sun-Alperin & Wang, 2008; Van Berkel, 1987). Positive or negative transfer may occur when L2 phonemes are consistent or inconsistent with L1 phonemes. When the same alphabets correspond to the same phonemes in both L1 and L2, this leads to positive transfer in L2 spelling. When different letters used to represent the same phonemes, negative transfer might take place. For example, the letter combination *ou* can represent the same vowel [au] in Dutch and English, L2 English learners who were literate in Dutch could transfer the GPC rules successfully (Van Berkel, 1987). However, German speakers may use *ie* that represents [i] in German to substitute *ee* in the English word *keep* (Luelsdorff, 1986). When the L2 phoneme is inconsistent with the L1 phoneme, the pronunciation of a L2 phoneme can be replaced by a L1 phoneme for L2 learners. However, if the grapheme for the L1 substituted phoneme corresponds to the same grapheme for the L2 phoneme, positive transfer can also be expected. Otherwise, negative transfer can occur. For instance, Welsh L1 learners used the vowel [a] in their L1 to replace the English vowel [æ], but the corresponding letters are the same in both orthographies. Therefore, the Welsh speaking students successfully acquired the English spelling letter *a* for [æ] (James et al., 1993). Alternatively, the English learners who speak Spanish as L1 may confuse the consonants [v] and [b] and used the letter *v* for *b* in the English word *cable* (Fashola et al., 1996). Last, Sun-Alperin and Wang (2008) compared the spelling errors of English vowels between English L2 young learners who spoke Spanish as L1 and their counterpart English L1 learners. They found that Spanish L1 children only made statistically significant more spelling errors on the English vowels that were phonologically

legitimate in Spanish. The finding suggested that the L1 Spanish literacy knowledge influenced their L2 English spelling development.

One qualitative case study conducted by Helman and Bear (2007) who investigated English learners' developmental patterns of L2 English orthograph. One of the important findings indicated that English learners followed the developmental patterns as English L1 children but demonstrated a developmental lag to acquire L2 English orthography. When advancing to the third grade, some English learners were still in the stage of using letter name knowledge to spell English words. In addition, the lag of behind their English-speaking peers may be attributed to their speech acquisition of English. For example, a second-grade Hmong student had phonological perception challenges with certain English sounds, and thus exhibited errors in her spellings.

To date, no study has been conducted to examine Pinyin spelling development and the characteristics of the Pinyin spelling errors in MI students who learn the mapping rules of two sets of phonology and orthography of L1 English and L2 Pinyin.

5.1.3 Research Questions

The present study aims to investigate Chinese phonology acquisition, Pinyin spelling proficiency, and the characteristics of their interlanguage phonology and spelling development in bilingual MI learners. This study asked the following two sets of questions. First, to what extent do MI students, in the absence of alphabetic Pinyin instruction, acquire Chinese phonology at the beginning of Grade 3 and what are the characteristics of MI students' L2 Chinese phonological acquisition? Second, to what

extent have MI students' developed Pinyin spelling skills after almost one academic year of systematic Pinyin instruction towards the end of Grade 3 and what are the characteristics of MI students' Pinyin spelling development?

5.2 Method

5.2.1 School Setting

Located in a Midwest state of the US, the school is an early total MI program implementing the intensive program model, with approximately 90% of instructional time in Mandarin from kindergarten for all subject matters. From the beginning of Grade 2, students are introduced to English literacy with seven English language arts class periods per week. Students learn simplified Chinese characters from kindergarten. At this school, Pinyin system is introduced in Chinese language arts at the beginning of Grade 3 for a year. The overall instructional time in Chinese decreases from 75% in Grade 3 to 50% in Grade 4. Chinese language arts, and social studies are taught in Mandarin, and English language arts, science, and math in English. Compared to other MI programs, the school sets relatively higher character recognition and production expectations. According to the self-report of the academic director, by Grade 5, students are expected to recognize about 2,000 characters and produce 1,500 characters. All classroom teachers are licensed and are native speakers of the languages in which they teach grade-level content (i.e., either in Mandarin or in English). At the administrative level, one English-speaking principal and one Mandarin-speaking academic director are responsible for executive and academic matters.

The school has excellent academic performance; the majority of the third graders could meet and exceed academic standards in reading and math in the state standardized assessments assessed in English. The racial composition of the school is mainly White and Asian. Only a small percentage of students receive free or reduced-price lunch or special education services. Although a noticeable proportion of students have Asian backgrounds, the majority of students speak English as their first or dominant language.

5.2.2 Participants

The present study was part of a larger research project that recruited a total of 76 third graders (39 girls and 37 boys; mean age = 9.6 years) at the school. There were 72 students who participated in the tasks at Time 1. One student dropped out of the study after Time 1, and another four students were only tested at Time 2, totaling 75 participants at Time 2. The majority of the participants had been enrolled in the MI program since kindergarten or Grade 1. Based on results reported in an earlier study conducted in the MI programs from the same state (Fortune & Song, 2016), most students' Chinese oral language proficiency levels were expected to range in Intermediate levels, using the rating scales and proficiency guidelines that are adapted for young learners and aligned with the American Council on the Teaching of Foreign Languages (ACTFL).

5.2.3 Pinyin Instruction

MI students at this participating school were taught the Pinyin system through a systematic curriculum and had been engaged in a variety of Pinyin reading and spelling activities throughout Grade 3. At Grade 3, the primary goal of Pinyin learning is to recognize Pinyin letters; spelling in Pinyin is secondary. The teachers introduced all Pinyin initials and finals in eight weeks, three or four symbols in each class period. The rest of the academic year was to practice reading and spelling Pinyin while learning Chinese characters. When teaching the Pinyin initials and finals, teachers introduced each symbol by connecting a familiar character that contains the sound the Pinyin symbol represents. For example, for the initial *j*, the teachers directed students to the Pinyin chart where there is a chicken, in Chinese 鸡/ji has a consonant [tɕ] that corresponds to initial *j* in Pinyin. Then, the teacher gave the example of 鸡/ji (chicken) in a phrase, 小鸡小鸡鸡鸡/xiaoji xiaoji jijiji (small chicken, small chicken, chicken chicken chicken). Students were asked to repeat the characters and phrases a few times in class. After learned some initials and finals, students were encouraged to practice combining the initials and finals with different four tones. Students were also asked to recall any syllables they were familiar with in their oral vocabulary. For example, when they combined the initial *m*, and final *ei*, to get the syllable *mei*, teachers asked the students what words they knew had the syllable *mei*. Students responded to the questions with *mei*4*mei*0 (younger sister), *mei*2*you*3 (don't have), *mei*3*guo*2 (America), etc. Sometimes, teachers had students spell some syllables on their white boards and then provided corrective feedback on their spellings. For some Pinyin symbols, teachers may make explicit comparison of the

sounds in English letters and in Pinyin. When students became familiar with the Pinyin orthography toward the end of the school year, teachers used Pinyin to teach characters by captioning Pinyin on top of unfamiliar characters in reading materials.

5.2.4 Design

This observational study aimed to explore MI students' speech acquisition and Pinyin spelling. Speech and spelling data from MI students were collected at two time points: Time 1 was at the beginning of September, 2018 when students had learned Chinese without Pinyin instruction for three years since kindergarten; Time 2 was during the second term of Grade 3 at the end of March, 2019 when students had received Pinyin instruction for almost an academic year. To address the research questions, three measures, described in detail below, were designed and collected: the task of Chinese Phonology and invented spelling using English letters (henceforth Invented Spelling-Eng) at Time 1; the task of Pinyin Spelling at Time 2.

5.2.5 Measures and Instruments

Chinese Phonology

Chinese word naming task was created to sample the unique phonological elements, including 20 consonants, 3 glides, 16 vowels, and 4 tones at least once (see Appendix K). The word list included 41 monosyllabic words, 5 bisyllabic words that were most likely to be familiar to the participating students at the beginning of Grade 3. The total phonological elements for all 51 syllables were 190 (see Appendix L). This task

differed from previous studies where picture-naming was used to elicit the words that contain a set of Chinese sounds for young children who could not read (e.g., Hua & Dodd, 2000). Using Chinese character stimuli was appropriate because Chinese characters did not contain phoneme-level sound cues or tones. The characters were printed black and white on one side of A4 white cards in a book stand display easel; high quality pictures and corresponding English translations were printed at the bottom of the characters or the page. Each individual participant was asked to name the words by a trained experimenter. If the child failed to name the target word in the test, the experimenter would point to the picture and English translation to assist the elicitation of the target sounds. If the child was still unable to pronounce the word, the child was asked to imitate the word demonstrated by the experimenter. Repetitions were noted on the test form. Their orally produced responses were audio-recorded. The audio files of the students' oral production were loaded and then transcribed in the qualitative data analysis software MAXQDA. The total number of participants who responded to this task was 72.

Invented Spelling-Eng

Invented Spelling-English was to tap Grade 3 students' ability to represent the Chinese sounds using English letters before Pinyin instruction. This measure expanded the task of Pinyin spelling used in Zhou and McBride (2015) by including 20 two-or three-syllable words or nonwords (see Appendix B). The measure included 19 unique SC consonants (17 syllable-initial consonants), 3 unique SC glides, 16 unique vowels, and 4 tones at least once (see Appendix C). All stimuli were recorded by an adult male voice

for consistency. The recording was played twice in order to make sure the participants heard the sounds. Children were asked to listen to the syllables twice and use their English literacy knowledge to spell. Because students had not been introduced to diacritic marks for tones, they were not asked to identify tones. The task was administered to a group of four to six students with paper and pencil. The total number of participants who responded to this task was 72.

Pinyin spelling

The Pinyin spelling measure assessed students' ability to spell Chinese sounds using Pinyin initials and finals. This task used the same recordings for the task of Invented Spelling-Eng. Children were asked to listen to the syllables twice and use their Pinyin knowledge to spell. The measure included 52 unique Pinyin initials and finals at least once (i.e., 17 initials, 35 finals) and the 4 unique tones (10 first tones, 11 second tones, 10 third tones, 10 fourth tones; see Appendix B). The task was administered in a group of four to six students with paper and pencil. The total number of participants who responded to this task was 75.

5.2.6 Data Analysis

The speech samples from the Chinese Phonology task were analyzed by phonemes and tones. The overall percentage of accurate production of the phonological elements and the number of phonological substitutions were calculated and reported in Table 5.1. The phonological substitution is defined as the differences between the

learner's sound realizations and target forms (Hua & Dodd, 2000). The substitutions were coded and categorized by type and frequency. Because the phonological elements could occur multiple times in the task of Chinese Phonology and students' responses may not be consistent in different word contexts, a sound was considered acquired when the child could correctly pronounce the sound two out of three (66.7%) times in the task (Hua & Dodd, 2000). The present study uses the stabilization criterion adopted from Hua and Dodd (2000) who suggested that when 90% of the children could accurately produce a phonological element at least 66.7% times in the task, the phonological element would be considered stabilized in the learner population. The phonological elements that were below 90% stabilization criterion and the common substitutions were reported in Table 5.2.

The speech production data was transcribed by the author of the study, who is a native speaker of Mandarin Chinese from mainland China. Twenty percent of the samples (14 samples) were randomly selected and coded by a native Chinese-speaking speech pathologist from Taiwan for inter-rater reliability. The percent agreement for the task was .98.

For the task of Invented Spelling-Eng, the spelling of each syllable was separated and coded by consonant, glide, and vowel. The same spelling for a phoneme were grouped and calculated by percentage. Only the same spellings used by more than 10% of participants (N = 72) were considered common spellings and reported in Table 5.4. In most cases, the letter-sound correspondence was considered on the basis of each individual letter for each phonological element, except the cases where multiple letters

could represent a phoneme (e.g., *ou* for [au]). When students were assumed to use multiple letters representing the same phoneme, the letters were separated and aggregated in different letter groups. For example, some students used both the letter *i* that corresponds to the high front vowel [ɪ] and the letter *u* for the high back rounded vowel [u] to represent the Chinese-specific high front rounded vowel [y]. These two letters were separated and grouped separately.

For the task of Pinyin spelling, each syllable was first separated and coded by the Pinyin initial, final, and tone. Pinyin spelling accuracy is the percentage of participants who spell a Pinyin symbol correctly. Pinyin spelling proficiency was grouped into three levels: emerging (below 50% accuracy), developing (between 50% and 75% accuracy), and proficient (above 75% accuracy). The Pinyin initials and finals may have multiple occurrences in the measure. If the Pinyin spelling accuracy in all occurrences appeared in the same level, the percentages were averaged and reported. Otherwise, the percentages were presented separately in different levels (see Table 5.3).

Pinyin spelling errors were further analyzed by consonant, glide, and vowel. The spelling errors were grouped and calculated by percentage, and only the common ones (more than 10%) were reported in Table 5.4, next to the common spellings for the same phonemes students spelled in the task of Invented Spelling-Eng before they were introduced to Pinyin.

5.3 Results

The first purpose of the study was to observe MI students' speech acquisition at Time 1. The second was to examine students' Pinyin spelling proficiency after they learned the Pinyin system toward the end of Grade 3 at Time 2. Additionally, the measure of Invented Spelling-Eng can reflect how the MI students represented SC sounds in their minds and the extent to which the cross-language influence on their Pinyin spelling.

5.3.1 Descriptive Analyses of Chinese Phonology Acquisition

Descriptive analysis of the accurate production of consonant, glide/vowels, and tones, and the number of phonological substitutions were reported in Table 5.1. In general, MI students had achieved high levels of accuracy rates in producing phonemes and tones, higher for tones and glides/vowels, and slightly lower for consonants. In another word, more than 99% of all vowels and tones were produced correctly, and about 97% of all consonants were articulated accurately. On average, each MI student made 4.25 phonological substitutions out of a total of 190 phonological elements.

Table 5.1 *Descriptive Analyses on Phoneme and Tone Accuracy and the Number of Phonological Substitutions (N = 72)*

	M	*SD*
Percentage of Consonants Correct (PCC)	97.25	2.73
Percentage of Glides/Vowels Correct (PG/VC)	99.26	1.19
Percentage of Tones Correct (PTC)	99.21	1.78
Number of Phonological Substitutions (NPS)	4.25	3.95

Note. The task of Chinese Phonology included 73 consonants, 66 glides and vowels, and 51 tones, with a total of 190 phonological elements.

The analysis of students' phonological substitutions showed that only three phonemes were below the 90% stabilization criterion, including the alveolo-palatal fricative [ɕ] and the high front rounded glide [ɥ] and its vowel pair [y]. The most frequent substitutions for the alveolar-palatal fricative [ɕ] was the AE or SC post-alveolar fricative [ʃ]/[ʂ] or the alveolar fricative [s], which are the sounds adjacent in the position to alveolar-palatal. The high back rounded vowel/glide pair [ɥ] and [y] were often substituted by the alveolar or post-alveolar approximant [ɹʷ] or its corresponding vowel pair [ɚ].

Table 5.2 *The Phonemes below the 90% Stabilization Criterion and the Common Phonological Substitutions*

IPA	Pinyin	Students Who Substituted *N (%)*	Common Substitutions
[ɕ]	*x*	21 (29%)	Alveolo-palatal fricative becomes post-alveolar [ʃ]/[ʂ] or dental alveolar [s]
[ɥ]	*yu*	28 (39%)	Palatal approximant [ɥ] becomes alveolar or post-alveolar approximants [ɹʷ]
[y]	*u/ü*	9 (12%)	The high front rounded vowel becomes rhotacized mid central vowel [ɚ]

Note. The total number of participants in this task is 72.

5.3.2 Results of Pinyin Spelling Proficiency

The average percentages of the correct spelling of the Pinyin initials, finals, and tones were reported in Table 5.3. In general, Pinyin initials were spelled more accurately than the finals. Of the 17 initials included in the measure, 12 of them achieved at the proficient level. These proficient spellings included five Pinyin initials (i.e., *j*, *sh*, *ch*, *h*,

and *r*) that correspond to the five SC consonants that differ greatly from AE. However, the spellings for *r* in *ri* and *j* in *ju* were less accurate than when these two initials were combined with other finals. The finals *zh* and *z* whose spelling proficiency achieved at the developing level and the most challenging Pinyin initials *x*, *q*, and *c* at the emerging level were the other five Chinese-specific consonants.

Table 5. 3 *Spelling Proficiency Levels of Pinyin Initials and Finals (N = 72)*

	Proficient (100—75% accurate)	Developing (75—50% accurate)	Emerging (Below 50% accurate)
Pinyin Initials (*n* = 17)	*b, p, d, t, s, m, l* *j, sh, ch, h, r*	*zh, z, r* in *ri, j* in *ju*	*x, q, c*
Pinyin Finals (*n* = 35)	*a, an, en, i* [i], *i* [ɻ̩], *ing*	*i* [ɻ̩], *e* [ɤ], *u* [y], *er,* *ang, ao, ong,* *ia, ian, iang, ie,* *u* [u], *ua, uan* [wan], *uang*	*ai, ei, ou, in, eng* *iu, iao, iong,* *o, uo, un, ui* *ü, ue, uan* [ɥɛn], *un* [yn] *i* in *ri*
Tones (*n* = 51)	Tone 4	Tone 1, Tone 2	Tone 3

The spellings for Pinyin finals were mostly at developing and emerging stages. Only five finals achieved at proficient level, including *a*, *an*, *en*, *i* [i], *i* [ɻ̩], and *ing*. These finals either consist of only one monophthong (i.e., *a* [a], *i* [i]), one apical vowel (*i* [ɻ̩]), or one monophthong with a syllable-final consonant [n] or [ŋ], that is, *an*, *en*, *ing*[2].

A similar pattern can also be observed at the developing level—the finals with less phonological elements were more likely to be spelled correctly. More than half of the students could accurately spell the five Pinyin finals with only one monophthong, including i [ɻ] *e* [ɤ], *u* [y], *and u* [u], the rhotacized mid central vowel *er* [ɚ], or one monophthong with a syllable-final consonant [n] or [ŋ] (i.e., *ang*, *ong*). Additionally, adding the glides [j] and [w] to these above-mentioned finals did not increase much difficulty. Other Pinyin finals students have achieved at the developing level included *ia, ian, iang, ie,* and *ua*, *uan* [wan], *uang*. The only diphthong that were spelled accurately by more than half of the students was the finals *ao* [ɑu].

The most challenging Pinyin finals for students to spell included the finals that represent the other three diphthongs, *ai* [ai], *ei* [ei], *ou* [ou], which are shared with AE. The three Pinyin symbols with omitted letters, i.e., *iu*, *un*, *ui*, were spelled at low accuracy level. The pair *o* and *uo* that represent the same sounds [wo], but have different spellings, were difficult for the students. The finals with the Chinese-specific glide/vowel [ɥ]/[y] were spelled at the low accuracy level, including ü [y], *ue* [ɥe], *uan* [ɥɛn], *un* [yn]. Additionally, adding the glide *i* [j] to the *ong* [uŋ] or diphthong *ao* [ɑu] that were at developing level to make *iong* [juŋ] and *iao* [jɑu] created another level of complexity for

[2] In the task, the syllable, jing1, was pronounced as [tɕiŋ].

the students. Lastly, the three finals with less elements at emerging level were *in* [in], *eng* [əŋ], and *i* [ɻ] in *ri* [ʐɻ].

Last, the fourth tone was accurately identified by the majority of the students. More than half of the students were able to identify the second tones and first tones accurately. The most likely misidentified tone was the third tone at the emerging level.

5.3.3 Characteristics of Pinyin Spelling Development

The third goal of the study was to characterize MI students' Pinyin spelling development, especially the cross-language influence from L1 English on the L2 Pinyin spelling. Students' frequent use of English letters to represent the same set of Chinese sounds were compared to their common Pinyin spelling errors by phoneme. Some patterns can be observed in Table 5.4.

First, all the 12 Pinyin initials and the five finals at the proficient level showed that the English letters that students used to spell the phonemes were the same as the Pinyin letters before they were taught Pinyin. It indicates that the Pinyin sound-letter correspondence rules for these symbols are shared with English GPC rules.

Second, the majority of the common Pinyin spelling errors (32 out of 44) can be traced to their common English spellings for the same set of phonemes before learning Pinyin. Although the cross-language influences were observed by comparing Invented Spelling-Eng and Pinyin misspellings, three distinct types of misspellings can be identified. One type of the Pinyin misspellings may mainly attribute to the insufficient phonological sensitivity to distinguish the SC sounds from AE sounds. For example, the

SC sounds and AE sounds, such as [ɕ] and [tʃ], [tɕ^{h}] and [tʃ], or [ɥ] and [ɹ^{w}], were very close to the students in perception and in production. Their misspellings represented that they used the letters corresponding to the AE sounds for the SC sounds. The second type is that students showed their phonological challenges in distinguishing some sound pairs in AE, and thus were not sensitive enough to the same sound pair in SC. In the Invented Spelling-Eng, students were confused by the nasal consonant pair [n] and [ŋ] and their corresponding letters. Similarly, these students substituted the letter *n* and *ng* for each other. In particular, the final *in* was spelled at a very low accuracy level—72% of students substituted *n* with *ng*. The third type of error was mainly due to the influence of English GPC rules. Although the students were able to identify the SC sounds (mostly these SC sounds are shared with AE sounds), they used English letters and letter combinations to spell these sounds. For example, for the three Pinyin finals *ai*, *ei*, *ou* that represent the diphthongs [ai], [ei], and [ou], students frequently used the English letters for the Pinyin finals, such as *i* for *ai*, *a* for *ei*, *o* for *ou*.

Another pattern of the common Pinyin misspellings observed is that some Pinyin symbols were orthographically challenging. For example, some students were confused by the three finals *o*, *uo*, and *ou*, or they sometimes spelled out the omitted letter *o* in *iu*, omitted the letter *i* in *ei*, added an extra *h* for *z*, or replaced the letter *d* for *b*.

In addition to the English literacy influence on the Pinyin spellings for the glides [j], [u], and [ɥ], another main error type was that students did not use any letters to identify the glides (see Table 5.5). The most often neglected glide was the high front unrounded [j] in the Pinyin finals. Students' spellings on the same set of syllables in the

tasks of Invented Spelling-Eng and Pinyin Spelling showed that 69% of the students on average did not use any letters for [j] in the Invented Spelling-Eng before Pinyin introduction. After learning Pinyin, there were still 35% of students who missed the glide in the Pinyin finals with [j]. The next often omitted glide was the high front rounded [ɥ] corresponding to the letter *u* in the Pinyin final *xue*. The percentage of students who missed the letter *u* remained similar in the two tasks before and after Pinyin instruction (28% vs. 29%, respectively). Last, the high back rounded [w] was most likely to be identified even before Pinyin training. The average percentage of students who did not represent the glide remained similar after the Pinyin training (16% vs.15%, respectively).

Table 5.4 *Common English Spellings in the Task of Invented Spelling-Eng (N = 72) and Common Pinyin Spelling Errors in the Task of Pinyin Spelling (N = 75)*

Phonological Elements in SC	Pinyin Letters in Contexts	Common English Spellings	Common Pinyin Spelling Errors (%)
	Syllable-Initial Consonants		
[ts]	*z*	*z, s*	*zh* (13)
[ts^{h}]	*c*	*t, s*	*s* (15)
[s]	*s*	*s*	
[tʂ]	*zh*	*j, g, ch*	
[tʂ^{h}]	*ch*	*ch*	
[ʂ]	*sh*	*sh, s*	
[tɕ]	*j*	*j, g, z*	
	j in *ju*		*g* (20), *zh* (15)
[tɕ^{h}]	*q*	*ch, t*	*ch* (31)
[ɕ]	*x*	*sh, s*	*sh* (55)
[ɻ]	*r*	*r*	
	r in *ri*	*r, er*	*er* (40)
[p]	*b*	*b*	*d* (13)
[p^{h}]	*p*	*p*	
[t]	*d*	*d*	
[t^{h}]	*t*	*t*	
[m]	*m*	*m*	
[x]	*h*	*h, w, y*	

[l]	*l*	*l*	
	Syllable Final Consonants		
[n]	*n*	*ng, n*	
	n in *in*		*ng* (72)
[ŋ]	*ng*	*ng, n*	*n* (14)
	Glides		
[j]	*i/y*	*i, e, y*	
[w]	*u/w/*	*o, u, w*	
	ø in o [wo]		*uo* (15)
[ɥ]	*u/yu*	*r, y, u, w*	*r* (67)
	Monophthongs and Apical Vowels		
[a]	*a in a, ia, ua, uan*	*a, o,*	
	a in ran	*a, o, e*	
[ɑ]	*a* in *ang, iang*	*a, o*	*o* (15)
[ɛ]	*a* in *ian,* y*uan*	*a, e, ø*	*e* (25)
[e]	*e in ie, ue*	*a, e*	*a* (13)
[ɤ]	*e* in *e*	*u, a, e*	*u* (16)
[ə]	*e* in *en*	*e, o*	
	ø in *un* (*e* omitted)	*e, i, a, ø*	*e* (25), *a* (20),
[ə]/[ʌ]	*e* in *eng*	*o, u*	*o* (28), *u* (23)
[ɚ]	*e* in *er*	*ar, er, r*	*ar* (11)
[i]	*i* in *i, in, ing*	*e, i*	*e* (23)
[ɻ]	*i* after *z, c, s*	*i, e, ø*	*e* (19)
[ʅ]	*i* after *sh, ch, zh, r*	*er, r, ø*	*er* (13), *e* (13), *r* (11)
[u]	*u* in *u*	*u, o, w, oo*	*o* (15)
[u]/[ʊ]	*o* in *ong/iong*	*o, u*	*a* (12)
[o]/[ə]	*o* in *o* [wo]	*o, a*	*ou* (19)
	o in *uo*	*o, a*	*ou* (19), *ow* (19), *o* (16)
[y]	*u* after *j, q, x,*	*r, u, i, o*	*i* (12), *r* (11)
	ü after n, l	*er, r, u, e, o*	*u* (36), *er* (21)
	Diphthongs		
[ai]	*ai*	*i, ai, y*	*i* (34)
[ɑu]	*ao* in *ao, iao*	*ow, aw, ao, ou*	*ou* (18)
[ei]	*ei or*	*a, ay,*	*a* (34), *ai* (12), *e* (13)
	i in *ui* (*e* omitted)		
[ou]	*ou,*	*o, ow*	*o* (45)
	u in *iu* (*o* omitted)		*o* (41), *ou* (27)

Table 5. 5 *Average Percentage of Participants who did Not Identify the Glides*

Glides after a Consonant	Average Percentage in Invented Spelling-Eng (N = 72)	Average Percentage in Pinyin Spelling (N = 75)
[j]	69%	35%
[w]	16%	15%
[ɥ]	28%	29%

Note. There were seven occurrences of [j], seven occurrences of [w], and only one occurrence of [ɥ] in the two tasks.

5.4 Discussion

Learning to read and spell involves the mapping between phonology and orthography (Perfetti, 2003). To become proficient Pinyin spellers, English proficient MI learners have to map Pinyin symbols to spoken Chinese. Because Pinyin spelling depends on MI students' sound acquisition, the findings in Chinese phonology acquisition could facilitate our understanding of MI students' Pinyin spelling development. The findings from two time points provided evidence that MI students have acquired high speech accuracy in Mandarin Chinese in absence of Pinyin instruction but have not developed a high level of Pinyin spelling proficiency after learning Pinyin for almost a whole academic year. The findings on MI students' phonological acquisition are consistent with previous research that immersion students could acquire high phonological competencies (Harada, 1999; Menke, 2010). However, the current findings reported that MI students' Pinyin spelling demonstrated a developmental lag in comparison to Chinese L1 children who could achieve high spelling proficiency fairly quickly after learning it for eight weeks (Cheung & Ng, 2003). This finding is consistent with studies on English learners learning English orthography (e.g., Helman & Bear, 2007).

After being immersed in Mandarin for three years without Pinyin, these young Chinese L2 learners have acquired the majority of the SC sounds: more accurate in producing tones, glides/vowels, and less accurate in pronouncing consonants. This finding is consistent with study with Chinese L1 children (Hua & Dodd, 2000). The possible explanation for high accuracy in tones and glides/vowels is that tones and vowels are compulsory in syllables (Hua & Dodd, 2000). The conventional wisdom is that tones are very challenging to acquire, but these young learners have achieved high accuracy in tone production. For these students who used Chinese most of the time in their classrooms, they may have developed awareness that the tone change could result in meaning change. However, tone identification was challenging, in part because it requires higher phonological sensitivity. The lack of high tone awareness, especially second and third tones suggests that these young Chinese L2 learners were still developing awareness to the suprasegmental elements. The insufficient tone sensitivity may also be related to pedagogy. In the field of teaching Chinese as a L2, researchers have questioned the teaching of the third tone because native speakers of Chinese may only use low tone without producing the falling and rising tonal contour in their pronunciation (Li, 2017). When two third tones are next to each other, the first third tone is pronounced as a second tone. This might in part explain why the third tone, which was often confused with second tone, was especially challenging for MI students.

With regard to the characteristics of MI students' speech acquisition, the findings evidenced that the major influence of L2 Chinese pronunciation is their L1 English pronunciation (Tarone, 2005). MI students could produce the phonemes shared in both

SC and AE but had challenges in acquiring the SC phonemes that exhibit the greatest discrepancies with AE, especially the alveolo-palatal [ɕ], and the high front rounded pairs [ɥ]/[y]. In particular, the alveolo-palatals [ɕ] were often replaced with post-alveolar [ʃ] or [ʂ] and the rounded glide/vowel pair [ɥ]/[y] were substituted with the alveolar [ɹʷ] and its rhotacized vowel pair [ɚ].

Unlike Chinese L1 children, the findings suggested that these MI students had not developed strong skills to identify the SC sounds and the skills to map the sounds to the Pinyin symbols after learning Pinyin for almost an academic year. Although a longitudinal or cross-sectional design may provide more information about Chinese L2 students' Pinyin spelling, this short-term assessment on Pinyin spelling proficiency could inform some of the patterns of Pinyin literacy development in MI students.

The first factor that influenced their Pinyin spelling was the number of phonological elements in the Pinyin symbols. MI students had higher spelling accuracy for the initials and finals with fewer consonants or simple vowels than the symbols with more and complex phonemes.

Second, the contrastive analysis used in this study demonstrated the cross-language influences by comparing the Invented Spelling-Eng and the Pinyin spellings before and after learning Pinyin. As James et al. (1993) Helman and Bear (2007) suggested, L2 spelling can be influenced by L1 spelling knowledge. It is important to note that this influence can happen in both positive and negative ways: both the correct and incorrect Pinyin spellings can be mostly attributable to the influence from their English literacy knowledge. When the phonemes and the corresponding letters are shared

in L1 English and L2 Pinyin, the Pinyin spellings exhibited positive transfer. When the Chinese specific sounds have approximation sounds in English that share the same letters in Pinyin and English, the positive transfer also occurred. Otherwise, negative transfer took place. These findings were consistent with earlier studies (James et al., 1993; Sun-Alperin & Wang, 2008). Another type of cross-language influence identified in the present study is that the developmental sequence may transfer in learning to read and spell in L2 (Tarone, 2005). Because MI students were also in the process of developing their phonological sensitivity and literacy knowledge in their L1 English, these students who had challenges to identify the sounds in L1 and the corresponding letters also exhibited challenges in identifying L2 Chinese sounds and mapping to the Pinyin spelling.

In addition to the cross-language influences from L1 English, another factor that results in Pinyin misspellings was the phonological challenges. Some Pinyin spellings require high phonological sensitivity, especially when one sound can influence the perception of the other neighboring sound. For example, when the alveolo-palatals [tɕ], [tɕ^{h}] and [ɕ] are followed by the Pinyin finals with the glide [j], a large number of the students were not able to identify the glide [j]. This is because the three consonants are produced with the constriction between the tongue and the hard palate to make the affricates similar to an approximant [j] (Lin, 2007). Although Pinyin instruction enhanced the phonological awareness in identifying the glide [j], there were still 35% of students who omitted the element, which led to the inaccurate spelling without the letter *i* in the finals. On the other hand, when the [tɕ] is adjacent to the high front rounded [y] in the

syllable *ju*, the perception of the alveolo-palatal [tɕ] was influenced by the vowel [y], which was often misconceptualized as the approximant [ɹʷ] or rhotacized central vowel [ɚ] in the students. Therefore, the alveolo-palatal was often perceived as the sounds of the post-alveolar [tʂ] or the post-alveolar [ʤ], represented by Pinyin letters *zh*, or English letter *g* (see Table 5.4).

Lastly, it is important to point out that some Pinyin finals were not reliable and thus created challenges to acquire. Most of the Pinyin symbols have one-on-one mapping at onset-rime level, but some finals have one-to-many and many-to-one sound to spelling relationships.

5.5 Implications

With over a decade of development and exploration, most Mandarin immersion programs do not introduce the Pinyin system until Grade 2 or Grade 3 (Everson et al., 2016). This curriculum design is endorsed by the fact that there might be cognitive constraints for young L2 learners to learn the mapping between the unfamiliar Chinese sounds and the Pinyin symbols. As the present study suggests, learning Pinyin spelling is very challenging for third graders who have already acquired high level of accuracy in Chinese sounds production. Presumably, it would be even more challenging for younger Chinese L2 learners (e.g., first graders) to learn the mapping between L2 Chinese sounds and Pinyin symbols with less developed phonological sensitivity. I interviewed two MI program administrators from two early total MI programs where the teachers piloted teaching Pinyin at Grade 1. They found that teaching Pinyin at Grade 1 was too

challenging for the students. One program delayed teaching Pinyin until Grade 3; the other extends the Pinyin introduction for an entire year of grade one.

In fact, students could acquire phonological sensitivity as they develop oral language at the same time of learning school subject content in the early schooling years (e.g., Goswami, 2001; Metsala, 1999). Additionally, the Chinese characters is the primary orthography, which corresponds to spoken Chinese at the syllable level; the alphabetic Pinyin is the orthography that maps on spoken Chinese at the onset-rime level. That means learning to read and write in Pinyin requires a different set of encoding and decoding skills from character reading and writing skills. Although Pinyin instruction could promote Chinese phonological awareness (Xu & Ren, 2004), the causal link between Chinese phonological awareness and Chinese word reading development has not been established (McBride & Wang, 2015). In addition, the experimental study in this dissertation suggested that Pinyin captioning does not facilitate learning Chinese words for MI students in teacher involved reading activities. The experimental study also suggested that the previous instructional time in early academic grades should be allocated to developing students' character knowledge and oral vocabulary knowledge that could have a reciprocal relationship with the development of morphological awareness, which is causally correlated with learning to read Chinese (e.g., Chow, McBride-Chang, Cheung, & Chow, 2008; Wu et al., 2009). Pinyin orthography does not map on English L1 children's phonological representation of Chinese, and, consequently, Pinyin input may interfere with children's Chinese pronunciation (Bassetti, 2006).

Results of the current set of studies indicate that late Pinyin introduction should be recommended for young Chinese L2 learners.

Mandarin immersion education is a context-driven foreign language program model where the school subject content is the focus of the instruction. However, pronunciation instruction should be incorporated in well-implemented immersion classrooms (Menke, 2010). To facilitate the learning of oral language and later the Pinyin system for MI students, we need to explore how to teach the challenging Chinese sounds for young Chinese L2 learners. For example, the Chinese-specific high front rounded glide/vowel pair [ɥ]/[y] are difficult to MI students. It was frequently replaced by rounded approximant [ɹʷ] or rhotacized vowel [ɚ] in students' oral production and represented with letter *r* or *er* in their spellings in English or in Pinyin. These evidences may explain that students were confused by the [ɥ]/[y] and [ɹʷ]/[ɚ] by only observing the lip rounding feature from their teachers. To make these two sounds more obvious for the students, minimal pairs can be effective to demonstrate the differences in these two sounds. For example, the teacher could use the two characters, instead of Pinyin symbols, 玉 [ɥy]4 and 日 [ɹɻ]4 to demonstrate the tongue positions when making these two syllables. In addition, teachers may also use cross-language examples to make explicit explanations between two similar sounds, such as the pairs [ɕ] in 西/xi and [ʃ] in *she*, [tɕʰ] in 亲/*qin* and [tʃ] in *chin*, [tɕ] in 金/*jin* and [ʤ] in *jean*. The challenge of using the cross-language activity is that language separation is predominant in the majority of MI programs, and MI teachers and program leaders may interpret this classroom language policy as no English at all. However, students may benefit from the instructional

intervention by using their L1 resources such as these to reduce errors and confusions in content-based foreign language classrooms.

Additionally, Pinyin instruction should be adapted to accommodate MI learners who have English literacy knowledge. In this study, the students demonstrated that they could transfer some English literacy knowledge to learn the Pinyin symbols. The teaching of the Pinyin symbols could be more flexible based on what students know from English and focus on some of the challenging ones that may have negative influence from the English alphabetic principle.

MI teachers should also pay special attention to the sound varieties in the Pinyin letters. For example, the final *i* has three corresponding phonemes, i.e., [i], [ɪ̟], [ɹ̩], rather than just one sound [i]. A common confusing instructional technique used by the teachers was to refer to the final *i* as [i] after Pinyin initials *z*, *c*, *s*, or *zh*, *ch*, *sh*, *r*. The teacher may demonstrate blending the initial *z* [ts] and final *i* [i] to make [tsɪ̟]. These may confuse alphabetic L1 spellers who rely on phonemic route to spell. In the spelling errors of the present study, students frequently used the letter *e* for [i] to replace *i* [ɪ̟]. One technique that is commonly used in mainland China is to treat the irregular spellings as a whole syllable that students do not need to separate and blend. For example, students could memorize Pinyin final *i* after *z* [ts], *c* [ts^{h}], *s* [s], or after *zh* [tʂ], *ch* [tʂ^{h}], *sh* [ʂ] and *r* [ɻ̩] without blending the Pinyin initials and finals.

Tone has been the instructional emphasis for Chinese L2 learners. Although the students could produce the tones at very high accuracy, they were still not proficient in identifying the tones. Teaching the four tones is more important to help students learn the

correct pronunciation, but the skill of tone identification may not be required in the Pinyin input method or dictionary searches. As Li (2017) argued that the falling-rising contour of the third tone is not used in real communication. It may be possible to teach the low tone, in lieu of the falling-rising tone, for Chinese L2 learners to avoid confusion. This awaits future research to examine the effectiveness of this pedagogy.

5.6 Conclusions

The present paper investigated L2 speech acquisition before Pinyin instruction and Pinyin spelling in MI students at Grade 3. The findings suggest that MI students had achieved high accuracy in the production of phonological elements without Pinyin instruction. Although these young Chinese L2 learners could pronounce most of the Chinese sounds, they were still in the progress of developing phonological sensitivity to distinguish SC and AE sounds and learning two sets of GPC rules in Pinyin and English. It was also found that MI students' Pinyin spelling exhibited strong influence from their L1 English literacy knowledge, in both positive and negative ways. Mandarin Chinese education for English-speaking young children is a new challenge. More research is needed to explore the effective ways in teaching the Pinyin system and the cross-language pedagogies to teach Pinyin by taking advantage of their English literacy knowledge. It calls for more future research on Pinyin literacy development for Chinese L2 and L1 children.

Chapter 6

Conclusions, Implications, Limitations, and Future Research Directions

6.1 Conclusions

This dissertation included three studies to provide empirical evidence regarding curricular decisions related to when to teach Pinyin and how to use Pinyin for elementary MI students. Although there are other factors to determine the when and how questions, which may be beyond the scope of this dissertation, important conclusions can be drawn from the three studies to help MI educators make informed decisions for their programs.

Study 1: Understanding the Relationship between Pinyin Spelling and Chinese Word Reading in Elementary Mandarin Immersion Students

The research question for this study is the following: (1) To what extent does Pinyin spelling predict Chinese word reading in Grade 3 MI students after controlling for a set of literacy-related variables based on the current theoretical understanding of learning to read in Chinese?

The findings from Study 1 suggest that the composite Pinyin spelling skill and the separate Pinyin onset-rime spelling skill were significant predictors of Chinese word reading for third grade MI students after controlling for a set of literacy-related skills. However, the unique variance explained by Pinyin onset-rime spelling is relatively small compared to the variance accounted for by Chinese vocabulary or the shared variance explained by Chinese phonological awareness, Chinese vocabulary, tone identification,

and the English spelling skill prior to Pinyin instruction. This finding contradicts my hypothesis that Pinyin spelling cannot predict Chinese word reading above and beyond the Pinyin literacy and Chinese character literacy related skills. One possible reason to explain this contradiction is that there might be other variables that could confound this correlation between Pinyin spelling and Chinese word reading. In the present study, I only identified the character and Pinyin literacy related core skills. As suggested in Bernhardt's (2011) compensatory model of second-language reading, there could be a large amount of unexplained variance of readers' L2 reading performance from social, cognitive, and sociocognitive dimensions. For example, the prediction of Pinyin spelling for Chinese character literacy may be due to the fact that the students had used similar learning strategies and experienced similar instructional methods to learn these two orthographies from the same group of teachers in their classrooms. In all, the correlational design precludes a causal claim between Pinyin spelling and Chinese word reading.

Study 2: Does Alphabetic Pinyin Facilitate or Hinder the Learning of Chinese Words in Meaningful Reading Activities? Evidence from Early Total Mandarin Immersion Students

The first question in this study is (1) Does the use of Pinyin facilitate the MI students' learning of Chinese words (i.e., knowing the pronunciation and explaining the meaning) in meaningful reading activities?

The use of Pinyin in reading materials did not facilitate the learning of Chinese words for MI students when the teacher was involved in meaningful reading activities. This finding confirmed my hypothesis that the use of Pinyin captions would not facilitate the learning of Chinese words when the teacher provided scaffolding and demonstrations in meaningful reading activities. In fact, students learned the Chinese words better without Pinyin than they did with Pinyin. This finding was consistent with a series of earlier studies on Chinese L1 children (e.g., Wu, Li, et al., 2002), indicating that Pinyin representation in reading materials is not more effective than a teacher's oral demonstration for students to learn the new Chinese words. One explanation for this counter-intuitive finding is, with Pinyin support as a crutch, students may lose the opportunity to retrieve the sound and meaning of the characters when they were supposed to wrestle with storing the characters' sound, shape, and meaning. Another possible explanation is that students were not proficient in Pinyin, so using Pinyin in reading materials may increase their cognitive load for learning the characters.

The second question in this study is to ask: To what extent is knowing the pronunciation of the Chinese words is associated with being able to explain their meaning among MI students?

The data shows that students' successful recognition of new Chinese words was strongly associated with their ability to explain the words' meaning. This finding is consistent with previous studies on Chinese L2 adult learners (e.g., Everson, 1998), indicating that meaning is the critical element that determines the learning of Chinese words. Additionally, multilevel model analyses showed that students learn the basic,

concrete Tier 1 words much better than Tier 2 words that express more abstract and nuanced meaning. The factor of word tier has a larger impact than whether or not Pinyin is provided. The findings provide a new perspective beyond the current phonology-based and orthography-based reading theories with regard to children's literacy development in Chinese.

Study 3: Learning Chinese Sounds and Pinyin Spelling in Elementary Mandarin Immersion Students

The first set of questions are (1) To what extent do MI students in absence of alphabetic Pinyin instruction acquire Chinese phonological elements at the beginning of Grade 3? What are the characteristics of their L2 Chinese phonological acquisition?

The third grade MI children in this study have acquired a high level of accuracy pronouncing isolated words, including the tones. On average, each student only made about four errors out of 190 possible phonological elements. In fact, tones and vowels exhibited higher accuracy than the consonants, which contradicts the conventional perception that it is difficult to learn tones in Chinese. However, some Chinese-specific sounds were challenging to the students, in particular, the alveolo-palatal fricative [ɕ] and high front rounded glide and vowel pair [ɥ]/[y], which exhibit the greatest discrepancies with AE. The most frequent substitutions included the SC alveolo-palatal [ɕ] replaced by sounds similar to post-alveolar [ʃ] or [ʂ], and the SC high front rounded glide/vowel [ɥ]/[y] substituted by the AE alveolar approximant [ɹʷ] or its vowel pair [ɚ], both of which have the lip rounding feature.

The second set of questions in this study are the following: (2) To what extent do MI students develop Pinyin spelling proficiency after systematic Pinyin instruction towards the end of Grade 3? What are the characteristics of Pinyin spelling development in MI students?

Pinyin spelling is challenging for MI students to acquire, especially the Pinyin finals and the identification of the third tone. Students learned Pinyin symbols with less phonological elements better than the complex symbols with more elements. Students' Pinyin spelling exhibited strong positive and negative influences from their L1 English literacy knowledge. Their Pinyin spelling errors also demonstrated a lack of strong phonological sensitivity. Additionally, students may be confused by unreliable Pinyin symbols. It is important to keep in mind that Chinese is the L2 for these young children; mapping the symbols to the phonological elements that they are still acquiring is a challenging task. The findings suggest that, in general, these L2 children have not yet developed a solid understanding of the Chinese phonological system, such as identifying all of the sounds or distinguishing the sounds from other similar sounds in both L1 English and L2 Chinese. Additionally, many Pinyin symbols do not correspond to the English L1 children's mental representations of Chinese sounds. Therefore, learning the mapping rules of Pinyin is much more difficult for Chinese L2 children than Chinese L1 children.

6.2 Implications for MI Program Design, Pedagogy, and Theory

6.2.1 Timing of Introducing Pinyin

In mainland China and Singapore, the common practice is to introduce Pinyin to Chinese L1 learners in Grade 1. However, this timing of Pinyin introduction should not be automatically applied to Chinese L2 young learners. Pinyin is challenging because in Grade 1, Chinese L2 children have not acquired a strong understanding of Chinese phonology like L1 children do, and as a consequence, L2 learners do not learn Pinyin as easily as L1 children. When I implemented the measures with the students, I asked them if they liked Pinyin. These third graders responded in a Midwestern way, "一点点 /yidiandian, [a little]." This suggested to me that they didn't like Pinyin because it might be too challenging to learn. Although I did not survey students who learned Pinyin since Grade 1 in other MI schools, my conversations with many MI teachers gave me a general picture that Pinyin is difficult for most MI students. For example, the participating school delayed Pinyin introduction to Grade 3, because they piloted teaching Pinyin in Grade 1 in the first year of establishing the program, and they found it was too difficult for the first graders. Another early total MI program I am familiar with extends Pinyin introduction to an entire academic year of Grade 1. In both programs, students are expected to recognize Pinyin symbols in the first year, but not to spell them.

From a character literacy development perspective, although Pinyin literacy can promote phonological awareness, it is still unknown whether or not phonological training can promote Chinese word reading. In fact, each character corresponds to a tonal syllable. Learning to read Chinese does not require phonemic awareness, or even onset-rime

awareness. For example, 水, in and by itself, is a syllable meaning *water*. Learning the character does not require the ability to separate the onset and rime or to identify the tones. Additionally, children do not necessarily develop phonological awareness through phonological training. Earlier studies have suggested that the phonological development, not the fully phonemic awareness (Read, Zhang, Nie, & Ding, 1986), is largely a result of vocabulary learning (e.g., Goswami, 2001; Metsala, 1999). Although phonological awareness or Pinyin spelling is a strong predictor of Chinese word reading for MI students, there is no evidence yet to establish the causal link.

As evidenced in Study 1, Study 2 and in other studies on Chinese L1 children (e.g., Shu et al., 2006; Tong et al., 2017; Zhou & Mcbride, 2015), morphological awareness and oral vocabulary have a much larger effect size than phonological related variables to account for Chinese word reading. It is also established that the relationship between morphological awareness and Chinese word reading is causal for Chinese L1 children (Chow et al., 2008; Wu et al., 2009). That is to say, morphemic (character) knowledge is critical in learning to read Chinese. The challenge for Chinese L2 children is that they have to develop oral vocabulary knowledge, Chinese character knowledge, and Chinese decoding skill at the same time, which are interdependent. Earlier studies suggested that immersion students develop L2 language proficiency more rapidly in the first few years, and their language proficiency develops more slowly in mid and high elementary grades (Grade 2 to Grade 5), which is characterized as a plateau effect (Fortune & Arrabo, 2006; Fortune & Ju, 2017) . Therefore, MI programs should maximize the instructional time to develop students' Chinese language proficiency and

character literacy, suggesting that late Pinyin introduction should be encouraged in most MI programs.

6.2.2 How to Use Pinyin

The timing of Pinyin introduction is also related to how to use Pinyin to learn Chinese characters for MI students. As suggested by the findings from Study 2 and earlier studies with Chinese L1 children (Li et al., 2011; Wu et al., 2009; Wu, Li, et al., 2002), Pinyin could interfere with the learning of Chinese words and, therefore, Pinyin captions should be avoided in teacher scaffolded reading activities. When I presented my preliminary findings in a summer course at the Center for Advanced Research on Language Acquisition (CARLA) this year, the finding that Pinyin does not promote or even interferes with character learning for MI students in teacher-involved activities was not surprising for MI educators. The MI teachers in the early Pinyin program with which I am familiar do understand that Pinyin notations can hijack students' attention to characters, so the teachers say they often ask the students to use ice cream sticks to block Pinyin notations on top of the characters in their reading materials. The purpose of teaching Pinyin and using Pinyin in this early Pinyin program is to facilitate their independent reading and writing activities. Additionally, computer literacy is required by the state in the second-grade curriculum. Students need to use the Pinyin input method to type characters on the computer as a component of their literacy instruction. The teachers are aware that Pinyin is challenging to MI students, so students learn Pinyin literacy as a content matter in their curriculum since Grade 1 and gradually develop Pinyin reading

and spelling proficiency, together with character literacy. When the teachers introduce new characters, they provide Pinyin notations in order to teach Pinyin reading and spelling. After the whole-group teaching, the students can use Pinyin to review newly introduced characters in independent reading activities or use Pinyin to replace unknown characters in writing activities. Additionally, Pinyin is not generally considered as a tool for MI students to learn new characters in independent reading. However, it is important to note that this early Pinyin program allocates 90% of instructional time in Chinese for three years and does not begin English literacy instruction until Grade 3. That is to say, this is the most intensive MI program model. For other program models with less school time in Chinese, it is important to allocate precious instructional time to teaching character knowledge and oral language proficiency in the early academic grades where independent reading and writing activities are less.

Pinyin may decrease Chinese L1 students' reading self-efficacy and motivation (Li et al., 2011). On the contrary, the teachers often argue that using Pinyin in independent reading and writing activities could increase their Chinese learning self-efficacy. Because Chinese L2 learners have much less character knowledge than Chinese L1 children, they could be more likely to read at a level of frustration and frequently encounter unknown characters in writing, which is very likely to decrease their confidence and motivation in learning Chinese.

To summarize, Pinyin introduction is a more complex topic than just focusing on whether or not it can facilitate Chinese character literacy. MI educators also need to consider Pinyin literacy itself, the use of Pinyin, literacy activities, program design, etc.

Based on my conversations with MI educators and the findings in Study 2 that Pinyin does not facilitate Chinese character learning for MI students in teacher-involved reading activities, I suggest that Pinyin should be avoided in reading materials in whole-group teaching. To promote Chinese character literacy for Chinese L2 learners and emergent bilinguals, teachers should maximize the learning opportunities to develop character knowledge and vocabulary knowledge, especially the Tier 2 words. Additionally, there might be cognitive constrains of learning Pinyin for young Chinese L2 learners, and there may be fewer independent reading and writing activities in early grades. Therefore, late Pinyin introduction should be recommended in most MI programs. This coincides with a decade of implementing the common practice of holding back Pinyin instruction in MI programs until Grade 2 or Grade 3 (Everson et al., 2016). In the programs where Pinyin is not introduced in early grades, students should be encouraged to take the opportunities to use other decoding and lexical inference strategies to guess unfamiliar characters. In the study on the use of reading strategy by MI students, Fortune and Ju (2019) found that both less and more proficient MI readers can use the phonetic components or the contextual information to make sense of the unfamiliar characters in texts. Additionally, cross-language facilitations could be designed to scaffold MI students' independent Chinese reading and writing activities, when they have not learned Pinyin. For example, in the measure of invented spelling-Eng, many third graders can use English letters to spell the Chinese syllables in a decodable manner. When they encountered unfamiliar characters in Chinese, they can be encouraged to spell them out using English letters, instead of leaving it blank or only turning to teachers for help.

6.2.3 Theorizing Chinese Reading Acquisition

To reiterate the important findings in Studies 1 and 2, Pinyin spelling made a relatively small impact on Chinese word reading, but Chinese vocabulary knowledge makes a much larger contribution to Chinese word reading; decoding Chinese words is strongly related with knowing the meaning of the word; and whether the word is concrete or abstract in meaning determines Chinese word learning.

The mapping theories describe reading acquisition of regularly and irregularly spelled words at different developmental stages in which children acquire the decoding strategies of using alphabetic principle, derivation, and analogy through phonologically rule-based learning (e.g., Ehri, 1998; Perfetti, 1985). This line of work has also been extended to research in Chinese reading acquisition (Chen, Shu, Wu, & Anderson, 2003). Alternatively, the other theory emphasizes orthography-based learning (Ho, Yau, & Au, 2003). However, these rule-based theories are not adequate to explain the strong association between meaning and word recognition in Chinese.

Based on the two routes in the Seidenberg and McClelland's (1989) triangle framework and the adapted triangle framework for Chinese at character level by Tan and Perfetti (1997), storing and retrieving sound can be connected directly with orthographic representations or indirectly via semantics. The large number of orthographic components and the opaqueness of the components in the characters make mapping via the direct route from orthography to phonology almost impossible. I hypothesize that learning to read Chinese reflects the second route in which meaning interacts in the mapping of orthography and phonology. This argument suggests that orthographic depth

may determine the function of semantics in establishing and retrieving the sounds from orthographic representations. For an orthography that mostly consists of regularly spelled words, learners only need to encode and decode the grapheme-phoneme rules in word reading. To learn a deep orthography, however, readers may rely on oral vocabulary knowledge to encode and decode them. Chinese characters represent a deep orthography that does not have phoneme-level representation, including the compound characters that have phonetic components (Anderson & Li, 2006). The phonetics in the compound characters are not reliable in cueing the sound of the whole character (Shu et al., 2003). It is possible to memorize the sounds and shapes for a handful of characters by rote, but the process of encoding and the ability to decode thousands of characters without grapheme-phoneme correspondences may depend on semantics to store and retrieve the holistic sounds from the orthographic representations. That is to say, the semantics could play a pivotal role on encoding and retrieving sounds from the orthography.

The mapping between sound, shape, meaning takes place at the character level—each character corresponds to a syllable and a morpheme (Tan & Perfetti, 1997). The findings from the reading miscue study in Fortune and Ju (2019) suggest that lexical knowledge may not be sufficient to facilitate the mapping between a character's sound and shape. Chinese L1 children have acquired strong oral vocabulary knowledge and, thus, could have derived some morphological awareness by being exposed to the morphemes in various contexts. However, Chinese L2 children, particularly MI students, develop their oral vocabulary knowledge mainly through input from their teachers in classrooms. Additionally, the understanding of morphemes in words for L2 learners can

also be restricted by the instructional activities. Chinese L2 learners may be only introduced to meaning concepts at word level in Chinese, in lieu of the character level. Therefore, the semantic representation can be at word level or character level, depending on the morphological structure of the words, children's exposure to the language, and their learning experiences. In most research studies, only morphological awareness tasks were used, not oral vocabulary knowledge tasks. In the morphological awareness tasks, only transparent morphemes were selected for participants to make compound words. The opaque morphemes in compound words were not considered. In fact, the correlation between morphological awareness and Chinese word reading was fully mediated by oral vocabulary knowledge (Tong et al., 2017). Therefore, it is appropriate, or even better, to replace a morphological awareness task with an oral vocabulary knowledge task to assess lexical meaning as a core skill in Chinese word reading research with L2 children. The pedagogical implication from this hypothesis is that teaching or researching the learning of reading the deep orthography of Chinese requires robust vocabulary instruction and character knowledge.

6.3 Research Limitations, Generalizability, and Directions for Future Research

This dissertation contributes to the field by including one observational and one experimental study to distinguish the correlational relationship between Pinyin spelling proficiency and Chinese word reading from the causal relationship between the use of Pinyin and Chinese reading acquisition. As discussed above and in Study 1, the correlation between Pinyin spelling and Chinese word reading cannot be interpreted as

causation because the causal link between phonological awareness and Chinese word reading has not been established. Even though the use of Pinyin did not facilitate Chinese word reading, it does not offer evidence to suggest whether or not increased phonological awareness is causally linked to higher Chinese word reading. This remains a focus on Chinese word reading that needs attention.

The generalizability of the findings to young students in other types of MI programs or bilingual children may be questionable. The present studies recruited participants only from a single early total MI program where Pinyin is introduced in Grade 3. The participants were mainly from middle class families, the majority of which were from White and Asian ethnic backgrounds. A handful of participants may speak a language other than English at home. The participating school is a public charter school. It sets high expectations on students' Chinese language proficiency and academic achievements and develops their own inhouse materials for instruction. Therefore, the students in this school may not be broadly representative of the whole MI student population in the US, especially not the Chinese heritage learners who may have a greater exposure to the Chinese language at home. Because of the higher number of early partial MI programs in the US, it is of particular interest to examine the Chinese phonological competence, Pinyin spelling accuracy, and Chinese word learning in these early partial MI students.

A longitudinal study design would increase or test the generalizability of the findings in Study 2 and Study 3. In Study 2, the difference in learning the sounds and meanings of Chinese words between Pinyin conditions and the No Pinyin condition was

not statistically significant. The study only included four stories and five focal words in each story. It is of interest to test the longitudinal effect of a learning condition on the learning of Chinese words. Additionally, in Study 3, Pinyin spelling was only tested toward the end of the academic year. Genesee, Geva, Dressler, and Kamil (2006) called for longitudinal studies on spelling errors because fossilized errors raise more educational concerns than bootstrapped errors.

Additionally, the speech production collected in Study 3 is only limited to isolated words. Because speech production in interactional discourse requires higher phonological sensitivity, participants may not be able to demonstrate equivalent phonological competence in spontaneous communication as high as they were in isolated word production. Therefore, the findings of their phonological accuracy in this study should not be interpreted to indicate their ability to speak in real communication. In addition, the approach used to analyze speech production was based on whether or not, instead of the extent to which, the participants can produce the target sounds. To better understand the patterns of phonological development in MI students may require an acoustic analysis that can accurately determine the bilingual effects.

Last but not least, more studies are needed to research Pinyin teaching and learning for English L1 children. Pinyin literacy is an important literacy component in MI education, but it has not received much attention in the field. Some acquisition and pedagogical questions need future research in early total and early partial MI programs, such as to what extent can MI students read Pinyin symbols? What are the more effective approaches to teaching Pinyin in MI classroom: more systematic introduction or

incidental introduction? How can teachers help MI students use their English L1 resources to learn Pinyin symbols rather than hinder their learning? To what extent does Pinyin facilitate the learning of Chinese words in independent reading and shared reading activities? To what extent does Pinyin facilitate comprehension of Chinese texts for Chinese L2 learners?

In addition to many more pedagogical questions that come from these studies, more importantly, this dissertation can give rise to many more theoretical questions on Chinese character literacy acquisition. Does phonological training, as a form of Pinyin instruction, promote Chinese word reading for Chinese L1 and Chinese L2 learners? If the Chinese characters correspond to syllables in absence of onset-rime level or phoneme level representations in the orthography, would a finer grain size of phonological awareness be important in learning to read Chinese for either Chinese L1 or L2 children?

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Appendix A

Character Learning Expectations for U.S. Mandarin Immersion Education

Compiled by Tara Fortune & Luyi Lien in 2016**

Table A.1 *Character Learning Expectations in Early Total (90:10) Mandarin Immersion*

	Yinghua Academy Charter School Minneapolis, MN		XinXing Academy Hopkins Public Schools, Hopkins, MN		Minnetonka Public Schools Minnetonka, MN	
Materials	In-House Reading Program		Singapore Reading		Singapore Reading	
K	R: 150	P: 80	R: 100	P: 20	R: 100-150	P: 50-100
1	R: 200-500	P: 250	*R: 500	P: 170	*R: 150-200	P: 100-150
2	R: 600-800	P: 500	R: 850	P: 320	R: 200-400	P: 150-250
3	*R: 800-1000	P: 700	R: 1,200	P: 470	R: 300-600	P: 200-350
4	R: 1,200-1,500	P: 800-1,000	R: 1,550	P: 620	R: 500-900	P: 350-500
5	R: 1,500-1,800	P: 1,200-1,500	R: 1,750	P: 720	R: 600-1,200	P: 350-600
6	R: 2,000	P: 1,600+	R: 1,950	P: 820	R: 650-1,500	P: 400-650
7	R: 2,200	P: 1,800+			R: 700-1,600	P: 400-700
8	R: 2,400	P: 2,000+			R: 750, 1,650	P: 450-750

Table A.2 *Character Learning Expectations in Early Partial (50:50) Mandarin Immersion*

	Utah Mandarin Immersion Salt Lake City, UT		Portland Public Schools Portland, OR		Chinese American International Schools (CAIS) San Francisco, CA
Materials	Mandarin Matrix		Singapore Reading		
K			R: 50-70	P: 50-70	Not using word count as indicators for learning expectations any more. (K. Chang, personal communication, Spring 2016)
1	R: 99	P: 31	R: 120-170	P: 120-170	
2	R: 200	P: 73	R: 200-270	P: 200-270	
3	*R: 367	P: 147	R: 300-390	P: 300-390	
4	R: 538	P: 226	R: 400-540	P: 400-540	
5	R: 813	P: 433	R: 500-690	P: 500-690	
6	R: 1,088	P: 640			

* Grades when pinyin is introduced and explicitly taught (R = recognition; P = production).

** Information is based on personal communications with program leaders and available online.

Appendix B

Priming Chinese Syllables Used in the Measure of Invented Spelling-Eng and Pinyin Spelling

	Pinyin	IPA		Pinyin	IPA
1	bu2 yao4	[pu] [jɑu]	11	ran3 hou4	[ɻan] [xou]
2	zhi1 shi3	[tʂɻ] [ʂɻ]	12	qün2 zi3	[tɕʰyn] [tsɻ]
3	huang2 se1	[xwɑŋ] [sɤ]	13	xiong2 ma3	[ɕjuŋ] [ma]
4	jiang4 xue3	[tɕjɑŋ] [ɕɥɛ]	14	tuan2 ju4	[tʰwan] [tɕy]
5	ri4 chu1	[ɻɻ] [tʂʰu]	15	wai4 po2	[wai] [pʰwo]
6	yüan2 qiu3	[ɥɛn] [tɕʰjou]	16	hong2 lü4 deng1	[xuŋ] [ly] [təŋ]
7	er3 duo1	[ɚ] [two]	17	hua4 jia4	[xwa] [tɕja]
8	li3 jie3	[li] [tɕjɛ]	18	bei3 jing1	[pei] [tɕiŋ]
9	chang2 cun1	[tʂʰɑŋ] [tsʰwən]	19	jin1 tian 1	[tɕin] [tʰjɛn]
10	qiao1 men2	[tɕʰjɑu] [mən]	20	pai2 dui4	[pʰai] [twei]

Note. IPA = International phonetic alphabet.

Appendix C

Answer Keys of the Possible English Spellings Representing the Standard Chinese (SC) Sounds and the American English (AE) Sound Equivalencies and Approximations in the Measure of Invented Spelling-Eng

Phonological Elements in SC	Pinyin Letters in Contexts	AE Sound Equivalents or Approximations	Possible Corresponding English Spellings
	Seventeen Syllable Initial Consonants		
[ts]	*z*	[z], [s], [t]	*z, s, t*
[ts^{h}]	*c*	[s], [t]	*t, s*
[s]	*s*	[s]	*s*
[tʂ]	*zh*	[ʤ]	*j, g*
[tʂ^{h}]	*ch*	[ʧ]	*ch*
[ʂ]	*sh*	[ʃ]	*sh*
[tɕ]	*j*	[ʤ], [z]	*j, g, z*
[tɕ^{h}]	*q*	[ʧ], [t]	*ch, t*
[ɕ]	*x*	[ʃ], [s]	*sh, s*
[ɹ]	*r*	[ɹ^{w}]	*r*
[p]	*b*	[b]	*b*
[p^{h}]	*p*	[p]	*p*
[t]	*d*	[d]	*d*
[t^{h}]	*t*	[t]	*t*
[m]	*m*	[m]	*m*
[x]	*h*	[h]	*h*
[l]	*l*	[l]	*l*
	Two Syllable Final Consonants		
[n]	*n*	[n]	*n*
[ŋ]	*ng*	[ŋ], [n]	*ng, n*
	Three Glides		
[j]	*i/y*	[j]	*i, e, y*
[w]	*u/w*	[w]	*o, u, w*
	ø in o [wo]		
[ɥ]	*yu*	[ɹ^{w}], [j], [w]	*r, y, w, u*
	Twelve Monophthongs and Two Apical Vowels in Rimes		
[a]	*a* in *a, ia, ua, uan*	[ɑ], [ʌ]	*a, o, u,*
	a in *ran*	[ɑ], [ʌ], [ɛ]	*a, e, o, u*
[ɑ]	*a* in *ang, iang*	[ɑ], [ʌ]	*a, o, u*

[ɛ]	*a* in *ian, uan/üan*	[æ], [ɛ]	*a, e, ø*
[e]	*e* in *ie, ue*	[e], [ɛ]	*a, e*
[ɤ]	*e* in *e*	[ʌ], [ə]	*u, a, o, e, i, y*
[ə]	*e* in *en*	[ə]	*e, o, u, a, i*
	ø in *un* (*e* omitted)	[ə]	*e, o, u, a, i*
	e in *eng*	[ʌ], [ə]	*o, u, e, a*
[ɚ]	*e* in *er*	[ɑ˞], [ɚ]	*ar, er, r, or, ur*
[i]	*i* in *i, in, ing*	[i], [ɪ]	*e, ee, i, y*
[ɿ]	*i* after *z, c, s*	[i], [ə]	*i, e, a, u, ø*
[ʅ]	*i* after *sh, ch, zh, r*	[ɚ], [ɹ]	*er, r, ir, or, ur*
[u]	*u* in *u*	[u], [ʊ]	*u, oo, o, w*
[u]/[ʊ]	*o* in *ong/iong*	[ɑ], [ʊ]	*o, u, w, oo*
[o]/[ə]	*o* in *uo*	[ɔ], [ʌ]	*o, a*
[y]	*u/ü* after *j, q, x, n, l*	[ɚ], [ɹ], [u], [i]	*r, u, i, e, y, o, w, ea*
	Four Diphthongs in Rimes		
[ai]	*ai*	[ai]	*i, ie, ai, y, ay*
[ɑu]	*ao* in *ao, iao*	[aʊ]	*ow, aw, ao, ou*
[ei]	*ei* in *ei, uei*	[ei]	*a, ay, ai, ey, ae*
[ou]	*ou* in ou, *u* in *iu* (*o* omitted)	[oʊ]	*o, ow, ou*

Note. ø means not using any letter to represent the phoneme.

Appendix D

Hierarchical Linear Regression Model Checking Plots

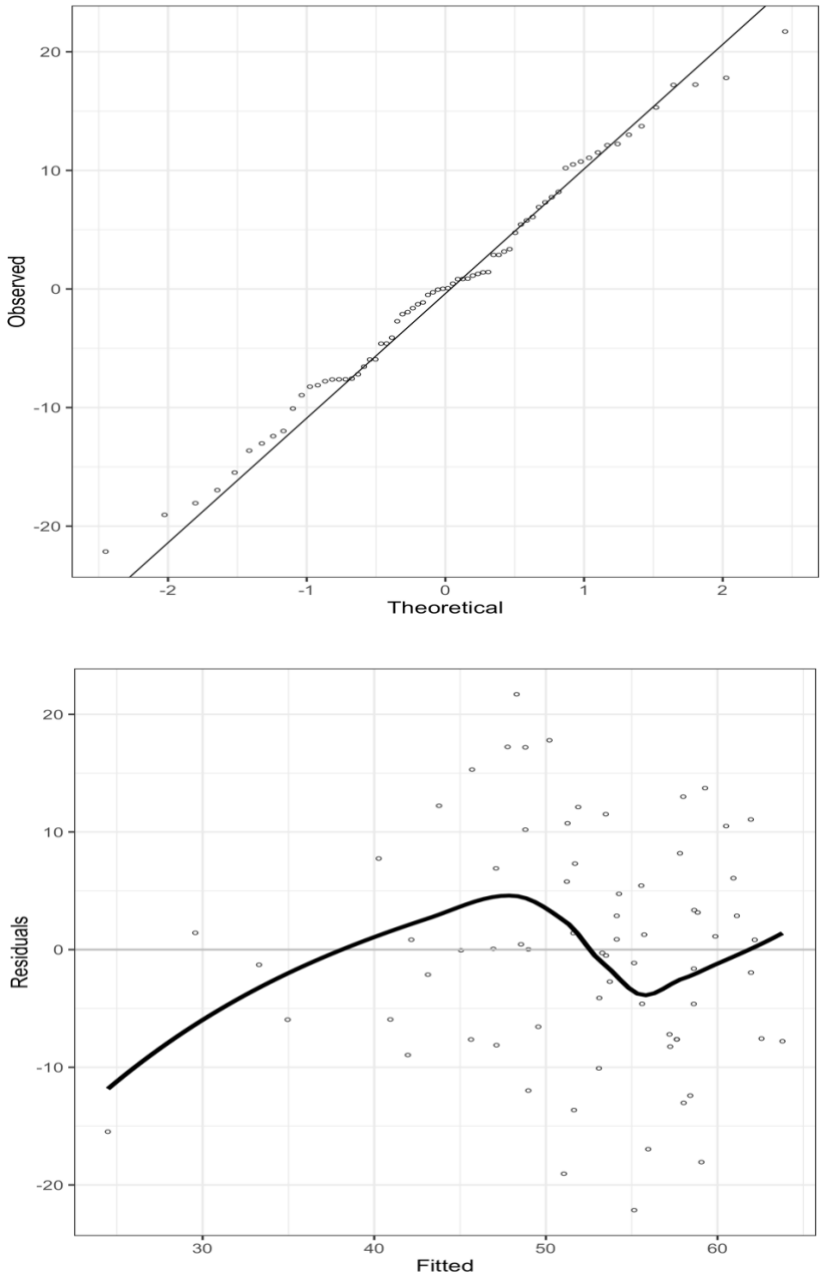

Figure D.1 Q-Q plot for normality (top) and residual plot (bottom) of the fitted values in Model 1

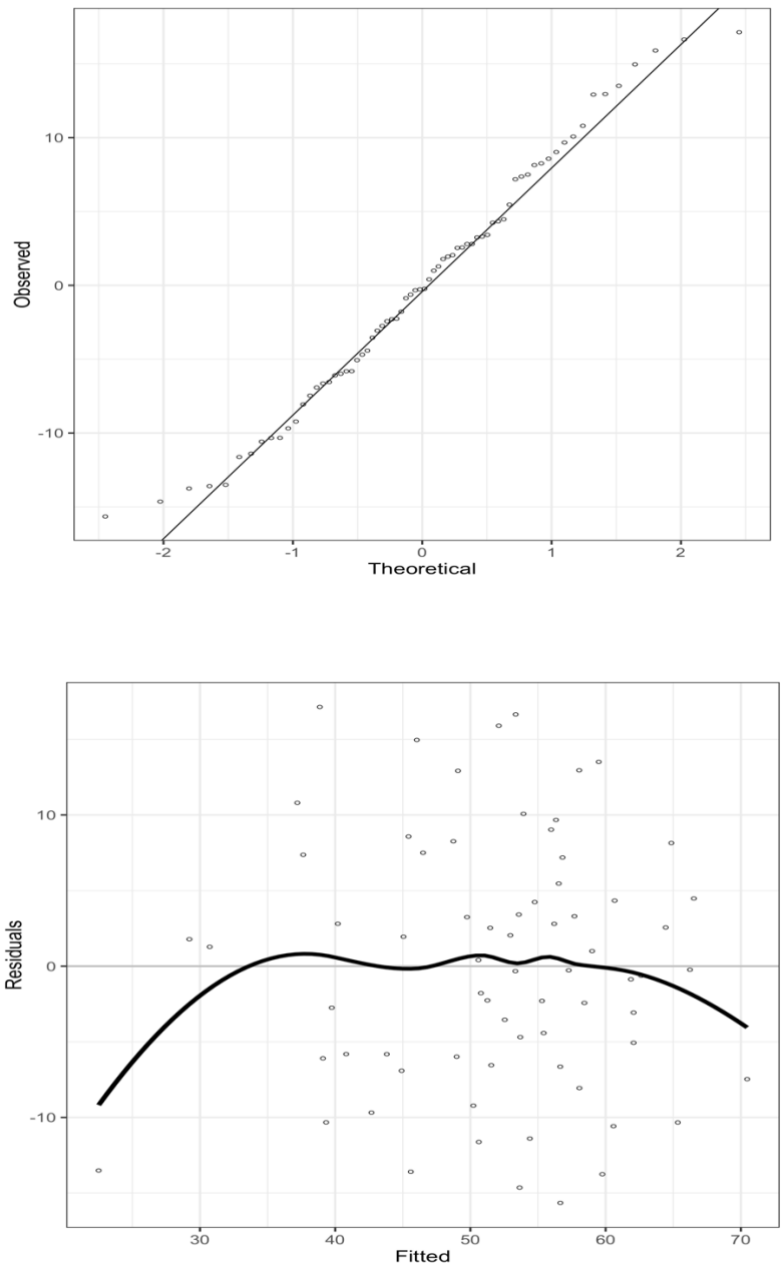

Figure D.2 Q-Q plot for normality (top) and residual plot (bottom) of the fitted values in Model 2

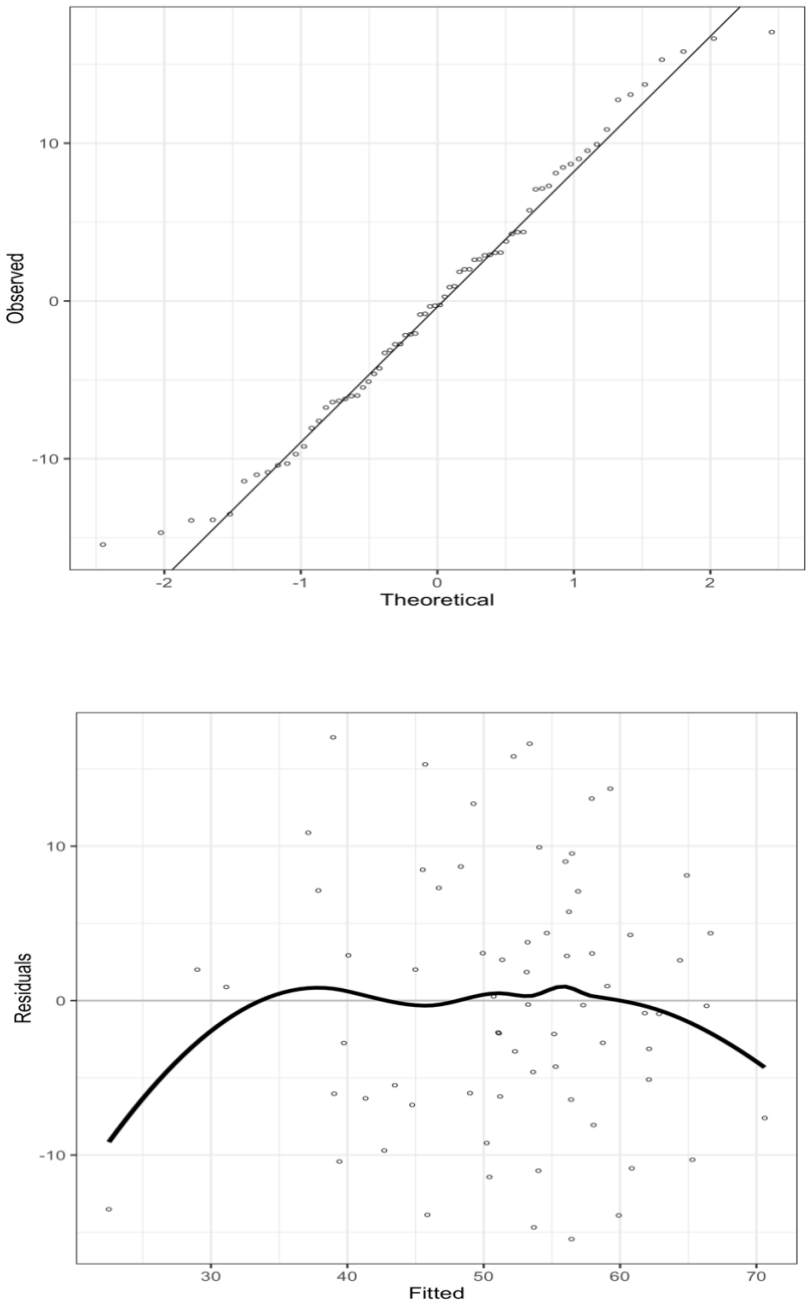

Figure D.3 Q-*Q plot for normality (top) and residual plot (bottom) of the fitted values in Model 3*

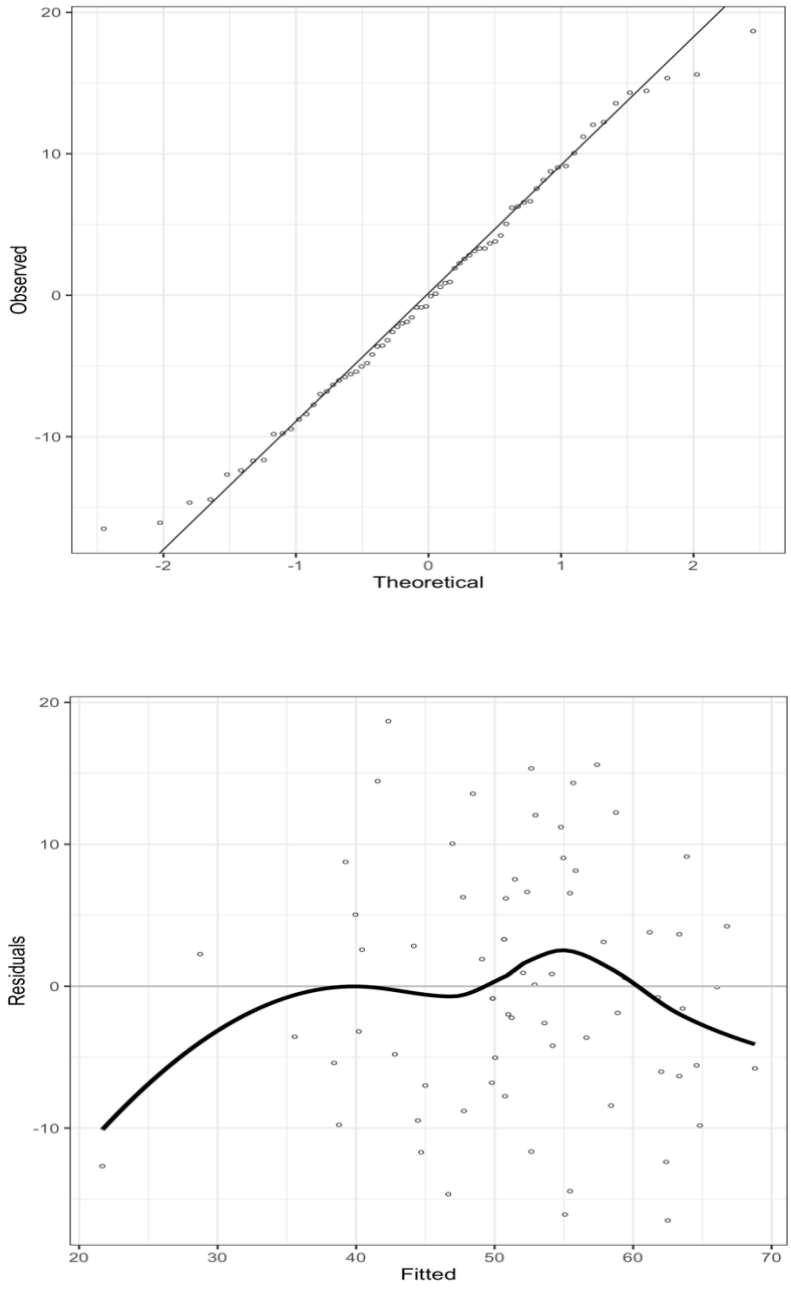

Figure D.4 Q-Q plot for normality (top) and residual plot (bottom) of the fitted values in Model 4

Appendix E

The First Pages of Story 4 in the Full Pinyin, Partial Pinyin, and No Pinyin Conditions used in the Experimental Study

First Page of Story 4 in Full Pinyin Condition

zhuō nòng rén de xiǎo hóu zi

捉弄人的小猴子

yǒu yī tiān, xiǎo tù zi kàn jiàn pú táo shù shàng de xiǎo hóu zi zài chī pú táo。

有一天，小兔子看见葡萄树上的小猴子在吃葡萄。

"nǐ yě xiǎng chī ma？" xiǎo hóu zi wèn dào。

“你也想吃吗？”小猴子问道。

First Page of Story 4 in Partial Pinyin Condition

zhuō nòng

捉弄人的小猴子

有一天，小兔子看见葡萄树上的小猴子在吃葡萄。

“你也想吃吗？”小猴子问道。

First Page of Story 4 in No Pinyin Condition

捉弄人的小猴子

有一天，小兔子看见葡萄树上的小猴子在吃葡萄。

“你也想吃吗？”小猴子问道。

Appendix F

Worksheet Examples Used in Pinyin Conditions and No Pinyin Condition in Story 3

Exercises in Full Pinyin and Partial Pinyin conditions: (1) Matching Pinyin Symbols and Words, (2) Choose the Correct Word for the Sentence

一、连线

道歉	zhuō nòng
捉弄	jǔ sàng
孤独	gū dú
沮丧	cuò wù
错误	dào qiàn

二、选词填空

1. 妈妈很生气，因为我今天_____弟弟了。
2. 金鱼很_____，它一个朋友都没有。
3. 我没有拿到生日礼物，非常_____。
4. 我做了一个_____的事，我把窗户打破了。
5. 他跟妈妈_____，因为他说谎话了。

Exercise in No Pinyin condition: (1) Choose the Correct Word for the Sentence

一、选词填空

道歉　　捉弄　　孤独　　沮丧　　错误

1. 妈妈很生气，因为我今天_____弟弟了。
2. 金鱼很_____，它一个朋友都没有。
3. 我没有拿到生日礼物，非常_____。

4. 我做了一个_____的事，我把窗户打破了。

5. 他跟妈妈_____，因为他说谎话了。

Appendix G

Standard Chinese and American English Consonants

Table G.1 *Standard Chinese Consonants*

	Bilabial	Labio-dental	Dental-Alveolar	Post-alveolar	Alveolo-palatal	Palatal	Velar
Stop	p p^h		t t^h				k k^h
Affricate			ts ts^h	tʂ $tʂ^h$	tɕ $tɕ^h$		
Nasal	m		n				ŋ
Fricative		f	s	ʂ	ɕ		x
(Central)				ɹ		j	w
Approximant						ɥ	
Lateral (Approximant)			l				

Table G.2 *American English Consonants*

	Bilabial	Labio-dental	Dental	Alveolar	Post-alveolar	Palatal	Velar	Glottal
Stop	p b			t d			k g	
Affricate					tʃ dʒ			
Nasal	m			n			ŋ	
Fricative		f v	θ ð	s z	ʃ ʒ			h
(Central)				ɹ^w		j	w	
Approximant								
Lateral (Approximant)				l				

Note. Cited from Ladefoged (1999) and Lin (2007).

Appendix H

Standard Chinese and American English Monophthongs and Glides

Table H.1 *Standard Chinese Monophthongs and Glides in IPA*

	Front		Central	Back	
	Unrounded	Rounded	Unrounded	Unrounded	Rounded
High	[i] / [j]	[y] / [ɥ]			[u] / [w]
Mid	[e]		[ə]	[ɤ]	[o]
Mid	[ɛ]				
Low	[a]			[ɑ]	

Table H.2 *American English Monophthongs in IPA*

		Front		Central	Back	
		Unrounded	Rounded	Unrounded	Unrounded	Rounded
High	Tense	[i]				[u]
	Lax	[ɪ]				[ʊ]
Mid	Tense	[e]				
	Lax	[ɛ]		[ə], [ʌ]		[ɔ]
Low		[æ]			[ɑ]	

Appendix I

Standard Chinese and American English Vowel Space

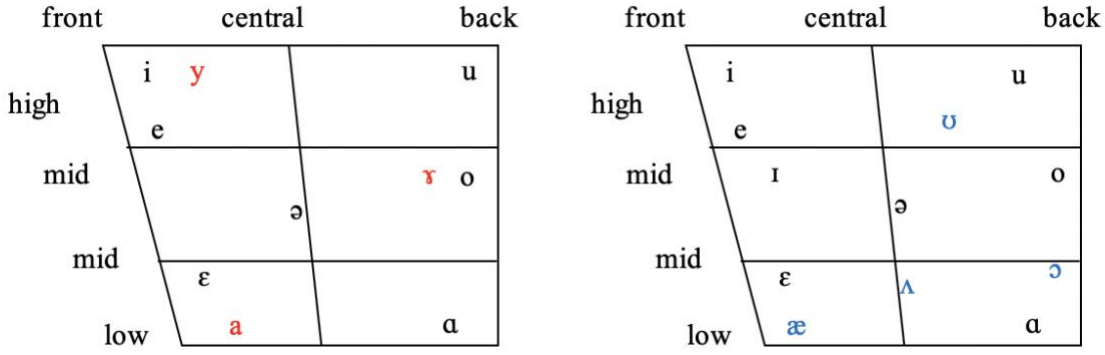

Figure I. 1 & Figure I. 2 Standard Chinese Monophthongs and American English Monophthongs (Lin, 2007; Ladefoged, 1999)

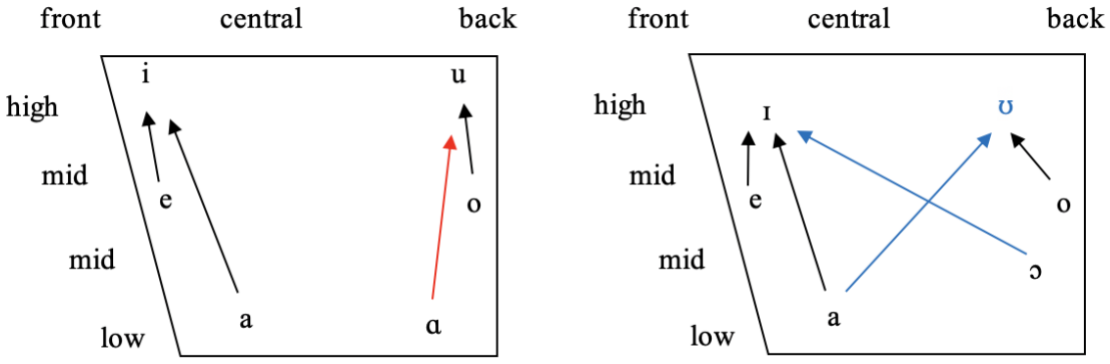

Figure I. 3 & Figure I. 4 Standard Chinese Diphthongs and American English Diphthongs (Lin, 2007; Ladefoged, 1999)

Appendix J

Pinyin Initials and Finals Represented by International Phonetic Alphabet (IPA)

Table J.1 *Pinyin Initials in IPA (N = 21)*

	Bilabial		Labio-dental	Dental-Alveolar		Post-alveolar		Alveolo-palatal		Palatal		Velar	
Stop	[p]	[p^h]		[t]	[t^h]							[k]	[k^h]
	b	*p*		*d*	*t*							*g*	*k*
Affricate				[ts]	[ts^h]	[tʂ]	[$tʂ^h$]	[tɕ]	[$tɕ^h$]				
				z	*c*	*zh*	*ch*	*j*	*q*				
Fricative			[f]	[s]		[ʂ]		[ɕ]				[x]	
			f	*s*		*sh*		*x*				*h*	
Nasal	[m]			[n]								[ŋ]	
	m			*n*								*ng*	
(Central)	[w]	[ɥ]				[ɹ]				[j]	[ɥ]	[w]	
Approximant	*w*	*yu*				*r*				*y*	*yu*	*w*	
Lateral (Approximant)				[l]									
				l									

Note. Pinyin letters w, y, yu are not considered Pinyin initials in *Scheme of the Chinese Phonetic Alphabet* (Committee of Chinese Writing System Reform, 1958)

Table J.2 *Pinyin Finals in IPA (N = 35)*

a Finals	IPA	[ɔɹ]	[a]	[ɤ]	[wo]		[ai]	[ei]	[ɑu]	[ou]	[an]	[ən]	[ɑŋ]	[əŋ]	
(*n* = 12)	Pinyin	*er*	*a*	*e*	*o*		*ai*	*ei*	*ao*	*ou*	*an*	*n*	*ang*	*eng*	
i Finals	IPA	[i]/[ɻ̩]/[ɻ̍]	[ia]			[iɛ]			[iɑu]	[iou]	[iɛn]	[in]	[iɑŋ]	[iəŋ]	[iuŋ]
(*n* = 10)	Pinyin	*i*	*ia*			*ie*			*iao*	*iu*	*ian*	*in*	*iang*	*ing*	*iong*
u Finals	IPA	[u]	[ua]		[uo]		[uai]	[uei]			[uan]	[uən]	[uɑŋ]	[uŋ]	
(*n* = 9)	Pinyin	*u*	*ua*		*uo*		*uai*	*ui*			*uan*	*un*	*uang*	*ong*	
ü Finals	IPA	[y]				[yɛ]					[yɛn]	[yn]			
(*n* = 4)	Pinyin	*ü/u*				*üe/ue*					*üan/uan*	*ün/un*			

Appendix K

Priming Chinese Characters and Their Corresponding Pinyin and IPA in the Measure of Chinese Phonology

	Character	Pinyin	IPA		Character	Pinyin	IPA
1	一	yi1	[ji]	24	长	chang2	[tʂʰɑŋ]
2	二	er4	[ɚ˞]	25	短	duan3	[twan]
3	三	san1	[san]	26	圆	yuan2	[ɥɛn]
4	四	si4	[sɻ̩]	27	黄	huang2	[xwɑŋ]
5	五	wu3	[wu]	28	绿	lü4	[ly]
6	六	liu4	[ljou]	29	黑	hei1	[xei]
7	七	qi1	[tɕʰi]	30	粉	fen3	[fən]
8	八	ba1	[pa]	31	金	jin1	[tɕin]
9	九	jiu3	[tɕjou]	32	风	feng1	[fəŋ]
10	个	ge4	[kɤ˨˩˦]	33	雨	yu3	[ɥy]
11	十	shi2	[ʂɻ̩]	34	云	yun2	[ɥyn]
12	百	bai3	[pai]	35	雪	xue3	[ɕɥe]
13	千	qian1	[tɕʰjɛn]	36	水	shui3	[ʂwei]
14	万	wan4	[wan]	37	热	re4	[ɻɤ˥˩]
15	上	shang4	[ʂɑŋ]	38	冷	leng3	[ləŋ]
16	下	xia4	[ɕja]	39	星星	xing1xing0	[ɕjəŋ] [ɕjəŋ]
17	左	zuo3	[tswo]	40	月亮	yue4liang4	[ɥe] [ljɑŋ]
18	右	you4	[jou]	41	花	hua1	[xwa]
19	中	zhong1	[tʂuŋ]	42	草	cao3	[tsʰɑu]
20	大	da4	[ta]	43	虫	chong2	[tʂʰuŋ]
21	小	xiao3	[ɕjɑu]	44	外婆	wai4po2	[wai] [pʰwo]
22	多	duo1	[two]	45	春节	chun1jie2	[tʂʰwən] [tɕje]
23	少	shao3	[ʂɑu]	46	熊猫	xiong2mao1	[ɕjuŋ] [mɑu]

Note. IPA = International phonetic alphabet.

Appendix L

Summary of the Phonological Elements in the Task of Chinese Phonology

Phonemes	Pinyin Symbols	Frequency
16 Consonant-Initials (total occurrence in the test = 41)		
[ts]	*z*	*n* = 1
[ts^{h}]	*c*	*n* = 1
[s]	*s*	*n* = 2
[tʂ]	*zh*	*n* = 1
[tʂ^{h}]	*ch*	*n* = 3
[ʂ]	*sh*	*n* = 4
[tɕ]	*j*	*n* = 3
[tɕ^{h}]	*q*	*n* = 2
[ɕ]	*x*	*n* = 6
[ɹ]	*r*	*n* = 1
[x]	*h*	*n* = 3
[p]	*b*	*n* = 2
[p^{h}]	*p*	*n* = 1
[t]	*d*	*n* = 3
[k]	*g*	*n* = 1
[f]	*f*	*n* = 2
[l]	*l*	*n* = 4
[m]	*m*	*n* = 1
2 Consonant-Finals (total occurrence in the test = 20)		
[n]	*n*	*n* = 9
[ŋ]	*ng*	*n* = 11
3 Glides (total occurrence in the test = 28)		
[j]	*i*	*n* = 12
[w]	*w/u/ø*	*n* = 11
[ɥ]	*u/yu*	*n* = 5
12 Monophthongs and Apical Vowels (total occurrence in the test = 39)		
[a]	*a*	*n* = 7
[ɑ]	*a*	*n* = 4
[ɛ]	*e*	*n* = 2
[ə]	*e, ø*	*n* = 7
[ɤ]	*e*	*n* = 2
[o]	*o*	*n* = 3
[e]	*e*	*n* = 3
[i]	*i*	*n* = 3
[y]	*ü/u*	*n* = 3

[u]	*u, o*	*n* = 3
[ɪ̈]	*i*	*n* = 1
[ɻ̩]	*i*	*n* = 1

4 Diphthongs (total occurrence in the test = 11)

[ai]	*ai*	*n* = 2
[ɑu]	*ao*	*n* = 4
[ei]	*ei/i*	*n* = 2
[ou]	*ou/u*	*n* = 3

4 Tones (total occurrence in the test = 51)

Tones	Frequency
First Tone	*n* = 14
Second Tone	*n* = 9
Third Tone	*n* = 13
Fourth Tone	*n* = 14
Weak Tone (not obligatory)	*n* = 1

Total = 190 phonological elements